

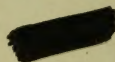
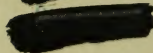
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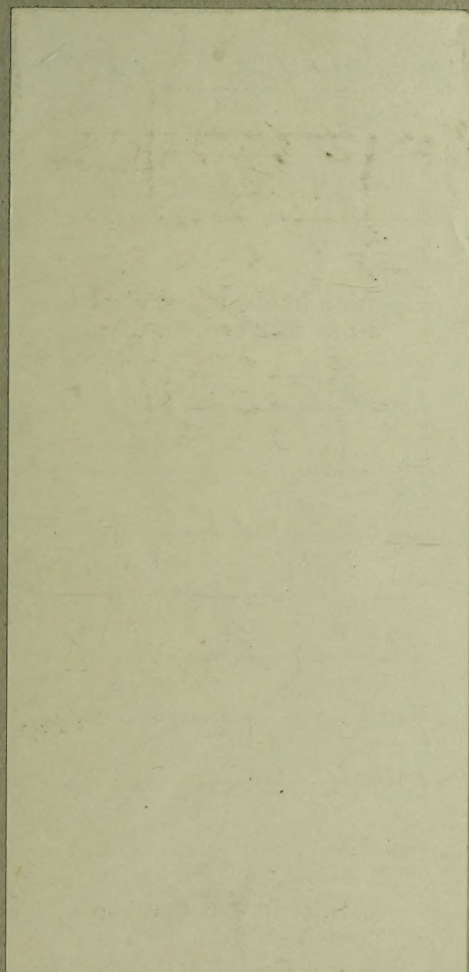
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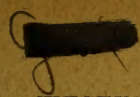
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GEOLOGICAL SURVEY.

BULLETIN No. 64.

MISCELLANEOUS REPORTS,

SERIES IV., Nos. 52-60.

*Issued under the Authority of the Hon. P. Collier, M.L.A.,
Minister for Mines.*

WITH 17 PLATES AND 35 FIGURES.



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PREFATORY NOTE.

This volume makes the fourth addition to the series of Miscellaneous Reports, the last of which was contained in Bulletin 59.

No special grouping either according to localities or subjects dealt with has been adopted in the arrangement of the various articles.

The reports are, with two exceptions (Nos. 55 and 57), entirely devoted to the economic aspects of Geological Science.

A. G. Maitland

GOVERNMENT GEOLOGIST.

Geological Survey Office,
Perth, 20th December, 1914.

392532

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(Director of the Survey.)

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TABLE OF CONTENTS.

	Page
PREFATORY NOTE	3
52. The Coal Resources of Western Australia : H. P. Woodward ..	7
53. The Mining Geology of Yerilla : J. T. Jutson	13
54. Certain Mining Centres at the South of the Yalgoo Goldfield : H. P. Woodward	46
55. Classification of Kalgoorlie Rocks : R. A. Farquharson	52
56. On Concentration tests of a Tungsten-Molybdenum ore from Callie Soak, Poona, Murchison Goldfield : Alex. J. Robertson ..	55
57. On Chloritoid and its Congeners with special reference to the Chloritoid at Yampi Sound : Edward S. Simpson	64
58. The Geology of Western Australia : A. Gibb Maitland	79
59. The Mining Fields of Western Australia : A. Gibb Maitland ..	92
60. Geological Observations in the Mulline, Riverina, and Ularring Centres, North Coolgardie Goldfield : F. R. Feldtmann	106

LIST OF PLATES.

FRONTISPIECE—MAP SHOWING THE LOCALITIES OF THE REPORTS
REFERRED TO IN THIS BULLETIN.

	Facing page
I. Geological Map of the Collie Coalfield with amended boundaries of the Collie Coal Measure Basin	10
II. Longitudinal section across the Collie Coal Field	12
III. Geological Map and section of the Chief Mining Area at Yerilla, North Coolgardie Goldfield	26
IV. Plan and Section of the Yerilla King Gold Mine, North Cool- gardie Goldfield	32
V. Geological Sketch Map of Yerilla, North Coolgardie Goldfield ..	44
VI. Map showing the Mining Centres at the South of the Yalgoo Goldfield	50
VII. Yampi Chloritoid, showing mode of twinning and arrange- ment of inclusions	75
VIII. Crystallographic Constants of Chloritoid	76
IX. Geological Sketch Map of Western Australia	90
X. Diagram showing the quantity (in tons) of gold ore treated, and the ounces of gold therefrom since 1886	102
XI. Diagram showing the quantity (in tons) of Copper Ore mined, and value of metal therefrom for each year, since 1855	104
XII. Diagram showing the quantity (in tons) of Black Tin produced and the value of metal therefrom for each year since 1899	104
XIII. Diagram showing the quantity (in tons) of Coal mined, and value thereof for each year since 1898	104
XIV. Map of Western Australia, showing the Goldfields and other Mining Districts; also the Distribution of the Useful Minerals	104
XV. Geological Sketch Map of the Country between Kalgoorlie and Mulline	128
XVI. Geological Sketch Map of Mulline	144
XVII. Ore Value Diagram of Mulline, Riverina and Ularring Centres	152

LIST OF FIGURES.

Fig.		Page
1.	Plan showing the Golden Eagle Group of Leases, Yalgoo Goldfield	46
2.	Plan showing the Porcupine Group of Leases, Yalgoo Goldfield ..	48
3.	Plan showing the Bonnie Venture Group of Leases, Yalgoo Goldfield	50
4.	Plan showing the Crusoe Group of Leases, Yalgoo Goldfield ..	50
5.	Chloritoid in mica schist, Yampi Sound	73
6.	Salmon Gum and Saltbush country between Waverley and Wangine Soak—Broad Arrow Goldfield	112
7.	Trig. Station, Ularring Rocks, North Coolgardie Goldfield ..	113
8.	Weathering of Granite—Ularring Rocks	114
9.	Small Gnamma Hole along a quartz vein—Ularring Rocks ..	115
10.	Sketch Plan of Gnamma Hole along a quartz vein, the latter intersecting pegmatite veins	116
11.	Breakaways, Wangine Soak, North Coolgardie Goldfield—showing darker laterite cap above white kaolinic matter, and the cutting back of cliff by watercourses	117
12.	Breakaways, Wangine Soak—showing gradual passage of ferruginous matter into laterite cap	118
13.	Outlier—Wangine Soak	119
14.	Breakaways, Wangine Soak—showing peculiar weathering of laterite	120
15.	Breakaways, Wangine Soak—Lenses of greenstone in decomposed granite exposed by watercourse	122
16.	Diagram showing relative weathering of amphibolite and intrusive dyke of quartz-porphyry, near Christmas Group—Broad Arrow Goldfield	123
17.	Water Reserve 3092—Broad Arrow Goldfield—outcrop of coarse granite showing large feldspar crystals	125
18.	Microphotograph [13809]: Serpentine	126
19.	Kurrajong trees in granite country—about two miles South-West of Reserve 3092—Broad Arrow Goldfield	131
20.	Microphotograph [13784]: Coarse-grained amphibolite, showing hornblende plates and feldspathic areas	133
21.	Former Mystery G.M.L. 548u, three miles South-West of Mulline, showing Granite-porphyry dyke intruding amphibolite ..	135
22.	Microphotograph [13788]: Microcline granite-porphyry	136
23.	Microphotograph [13787]: Junction between fine-grained amphibolite and granite-porphyry	137
24.	Mystery G.M.L. 548u—Mulline—Cross section	138
25.	Mystery G.M.L. 548u—Mulline—Longitudinal section	139
26.	Specimen [13787]: Former Mystery G.M.L. 548u, Mulline, showing junction between amphibolite and granite-porphyry ..	140
27.	Cardinal G.M.L. 954u—Ularring—Sketch Plan	141
28.	Microphotograph [13794]: Quartz-porphyry showing cracked quartz phenocryst and micacised feldspar phenocryst ..	141
29.	Former Off Chance G.M.L. 766u—Ularring—Diagram	142
30.	Microphotograph [5016]: (a.) Microcline showing typical structure and albite intergrowths; (b.) Another view of the same	143
31.	Microphotograph [13790]: Basaltic dolerite (?) showing the pseudomorphous phenocrysts and the feathery nature of the ground-mass	144
32.	Laterite escarpment on hill, two miles West of Riverina	146
33.	Former Cooladdie G.M.L. 330u—Mulline—Cross section showing quartz lenses	147
34.	Outcrop of quartz reef. Former Derby G.M.L. 666u—Ularring ..	149
35.	Riverina Group of Leases	151

MISCELLANEOUS REPORTS.

SERIES IV.

52.—THE COAL RESOURCES OF WESTERN AUSTRALIA.*

BY H. P. WOODWARD.

(With a Map and Section; Plates I. and II.)

CONTENTS.

	Page
The Collie Coalfield	7
Locality	7
Physical features	7
Geological characteristics	7
Geological Age	9
Extent of measures	9
Character of the Coal	9
Chemical composition	10
Mining	11
Kimberley	11

THE COLLIE COALFIELD.

Locality.—Up to the present time only one area has been discovered in this State in which marketable coal seams have been proved to exist. This is situated upon the Collie River, about 100 miles to the southward of Perth (the capital).

Collie is connected by railway line with the two principal south-western ports, Fremantle being 136 miles *via* Perth and Bunbury 41 miles.

Physical Features.—The Collie basin is situated in a depression at the back or to the eastward of the Darling Range. The basin is 600 feet above the sea level from which it is separated by a granitic ridge and the coastal plain.

Geological Characteristics.—There are absolutely no indications of the presence of stratified rocks, the entire extent of the coal measures being concealed beneath either sandy swamps or ferruginous laterite ridges, the whole basin being surrounded by gneissic granite. Attention was first directed to the existence of coal seams by a shepherd a good many years ago, who discovered one outcropping in the bed of the river during an exceptionally dry season, but it is only recently that mining operations were commenced.

* Written for the International Geological Congress, Canada, 1913.

Boring and shaft sinking prove the formation to consist of a series of sandstones, grits and micaceous shales associated with a number of coal seams, the largest of which is about 17 feet in thickness.

Samples of these shales and sandstones have been described by Mr. Chapman as follows* :—

The collection of plant remains from the Collie Coalfield consists of *Glossop teris* leaves and stem fragments which occur on pieces of carbonaceous shale, and on the surfaces of a whitish sandstone with thin, black carbonaceous partings. The sandstone specimens and some of the shales are from cores obtained by boring.

The Shales.—Some of the plant-bearing shales are earthy in texture, and show a fair sprinkling of mica foliae on the split surfaces. The majority of the slabs bearing the finest leaves consist of a close-textured bituminous shale, which shows a bright surface where abraded.

A microscope section of this bituminous shale proves it to consist of fine, amorphous, hydro-carbonaceous particles, and only in one case was anything like a spore detected. This had the appearance of a sub-elliptical cell, with a clear circular area situated near to one side of the interior, and bore some resemblance to one of the cells of *Pila*, an organism whose remains constitute the bulk of the European bogheads.

The Sandstone.—There are two specimens of sandstone, both being cores from a boring. One of these is a greyish rock with numerous papery carbonaceous layers averaging about five mm. in thickness, the intervening sandstone layers being about two mm. thick. This specimen is somewhat micaceous, both white and brown micas being present, the former preponderating. On one surface of the core a flattened stem-like fossil occurs, apparently of the nature of a plant stem or a rhizome. The rock shows distinct cross-bedding, pointing to the shallow water conditions prevailing when the deposit was laid down.

The second sandstone specimen shows only one carbonaceous seam, although the core is 35 mm. thick. The stratification lines have a slight dip, and there are indications of current bedding. This specimen reveals some interesting structural features when submitted to a microscopic examination. The granules of which the rock consists are largely made up of quartz, some felspar and numerous garnets, with occasional mica. The rock is loosely compacted, the interstices being occupied by a white, powdery material, probably of the nature of kaolin. Of the mineral constituents of the rock garnet is the most abundant ; it is usually in fractured grains, but sometimes crystal faces are visible, and the colour varies from dark ruby to almost colourless. Quartz occurs next in abundance, usually in rounded, but not polished, grains ; and sometimes shows included strings of cavities and acicular rutiles. The felspar is more generally orthoclase, often showing zoning ; occasionally there are fragments of microcline, with perthite structure. This material was probably derived from the garnetiferous granites or gneisses which are found in this locality.

Amongst the finest powder of this rock, after crushing and washing, there occurred a few examples of Foraminifera of unusually minute dimensions, and probably dwarfed on account of their brackish water habitat.

On treating the powder of this sandstone with hydrochloric acid a slight effervescence was noticed due, no doubt, to the presence of a few remnants of foraminiferal tests.

Limestones are entirely absent, whilst the only palaeontological evidence of the geological age of these beds is afforded by the plant

* F. Chapman, Palaeontologist to the National Museum, Melbourne, Victoria. Bull. 27, Geol. Survey, W.A., 1907, pp. 10 and 11.

remains exposed in the shales after weathering. These consist of *Plantæ* (*Glossopteris browniana*, *G. indica*, *G. angustifolia* (?) *G. gangamopteroides*, Rhizoma of *Glossopteris* (*vertebraria*), Foraminifera *Endothyra*, *Valulina*, *Bulimina*, *Truncatulina* and *Pulvinulina*.

Geological Age.—Considerable divergence of opinion has existed with regard to the age of this coal, for not only did some palæontologists determine the plant remains as belonging to the Mesozoic Series, whilst others claimed that they were Permo-Carboniferous, they are now, however, unanimous in classing them under the latter head. My own leaning all along has been towards assigning to this coal an age of either older Mesozoic or intermediary between that and the Palæozoic, my reason being entirely based upon its chemical composition, which is almost identical with those of that age in other parts of the world, whilst further, I contend that the composition of the coal which is indicative of the character of the vegetation is more conclusive than one or two associated plant leaves.

Extent of Measures.—As previously stated the area lies in a granite basin, therefore the mapping in of its extent is a matter of great simplicity since the character of the soil and flora changes immediately this junction is crossed even where no rock is exposed. This area we estimate at roughly 95 square miles. A considerable amount of boring has been carried on which has demonstrated the existence of a great number of seams but with the exception of about four localities at which large seams have been worked sufficient boring has not as yet been done to determine the actual area over which seams extend.

Character of the Coal.—The coal is what would, 30 years ago, be described as a black lignite but now as a non-caking bituminous coal high in moisture. It is black, dirty to handle, partly of a splinty character, and partly composed of bright layers alternating with soft bands which present the appearance of compressed soft wood charcoal.

The splint coal is extremely tough to cut or break, but rapidly develops cracks upon exposure to dry warm air which renders it unsatisfactory for long railway journeys or for storage upon the goldfields, since it rapidly slacks with the formation of smalls. It is highly hygroscopic, for even when dried in the laboratory it so rapidly absorbs moisture from the air that great care has to be exercised in weighing.

It does not kindle so rapidly as the coals from New South Wales, but it burns with the evolution of very little smoke without the formation of cinders until nothing but a bulky but light ash of a white or reddish colour is left. It neither fuses nor cokes and has a short flame length.

Chemical Composition.—The following tables have been prepared from a number of tests made in the Departmental Laboratory by Mr. E. S. Simpson, B.E., F.C.S.:—

Specific Gravity	..	..	..	..	1.349
Proximate Analysis—					
Moisture	..	..	..	..	21.18
Volatile hydrocarbons	..	..	..	..	28.99
Fixed carbon	..	..	..	..	43.73
Ash	..	..	..	..	6.10
					100.00

Ultimate Analysis.

						Fresh Coal.	After deducting Moisture.
Carbon	..	..	..	..	..	54.51	69.80
Hydrogen	..	..	..	..	..	3.46	4.43
Oxygen	..	..	..	..	..	13.23	17.00
Nitrogen	..	..	..	..	..	1.07	1.37
Sulphur	..	..	..	..	..	.53	.68
Ash	..	..	..	..	..	5.28	6.72
Moisture	..	..	..	..	..	21.92	..
						100.00	100.00
Calorific Value, B.T.U.	..	..	..	..	..	9637	12231
Ratio—							
Volatile hydrocarbons				1		Hydrogen	1
Fixed Carbon				1.55		Carbon	16.3
						Oxygen	1
						Carbon	4.35

These samples were taken from the face in the mine and placed in air-tight tins, and tests were made with regard to the quantity of moisture given off upon exposure to dry warm air which amounted to 7.66 per cent. in 31 days, after which no further change took place; therefore the average market coal is lower in moisture than these fresh samples and has a relatively higher calorific value.

The following are the results obtained at some locomotive trials in 1905 from a number of samples:—

Calorific value, B.T.U.	..	..	10,470
Moisture, per cent.	..	..	13
Ash, per cent...	..	..	6

It will be noticed from the above that the calorific value of the coal upon the market is about intermediary between that given by the samples containing mine water and the dried ones.

LLETIN Nº64 PLATE I.

+ Map

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Outcrop of Coal Seams

For Longitudinal Section A.B. and B'C. see next Map



The following give the composition of three samples of ash:—

Silica, SiO_2	..	..	..	..	35.29	61.18	28.29
Titanium Oxide, TiO_2	..	..	..	..	1.38	1.66	1.75
Phosphoric Oxide, P_2O_5	..	..	..	..	.16	trace	8.31
Vanadic Oxide, V_2O_5	..	..	..	..	.21	.10	.02
Sulphur trioxide, SO_3	..	..	..	..	2.43	.58	3.30
Potash, K_2O	..	..	..	..	.18	.20	.32
Soda, Na_2O	..	..	..	..	.39	.72	.80
Lime, CaO	..	..	..	..	2.94	1.61	5.39
Magnesia, MgO	..	..	..	..	2.18	.51	3.99
Manganese Oxide, Mn_3O_4	..	..	..	..	1.35	.43	trace
Iron peroxide, Fe_2O_3	..	..	..	..	36.57	5.67	23.38
Alumina, Al_2O_3	..	..	..	..	16.59	27.63	24.58

The greater part of the iron in the ash exists in the coal in the form of ferrous carbonate. The amount of pyrites being small, ranging from 0.5 to 1.1 per cent.

Mining.—There are only four companies operating upon this field, who work the whole or a portion of the largest seams by incline plane haulage, the height of the coal worked varying from 6 to 10 feet, whilst the system adopted is the pillar and stall.

Owing to the easy grade of the seams and the short period over which they have been worked the deepest vertical depth as yet attained is only 250 feet, but it is highly probable that a pair of vertical shafts will be shortly put down to a depth of 1,000 feet with the object of working a large seam which has been thrown down about 500 feet by a fault.

The coal is cut with electric band cutters and also bored for shooting by the same power, black powder being used as the explosive.

As the mines are absolutely free from gas naked lights are employed, whilst, provided good ventilation is available, there is no danger from choke damp.

Although Collie is the only coalfield upon which any active operations are being carried on, there are other districts in the State in which lignites and brown coals occur. No detailed geological surveys have yet been carried out, such as would enable even an approximate estimate to be made of the area or the quantity of coal available.

KIMBERLEY.

In the Kimberley Division in the far north of Western Australia a seam of hydrous bituminous non-caking coal, somewhat similar to that occurring at Collie, has recently been found in well sinking on Lower Liveringa Station, some distance to the south of Derby, in the valley of the Fitzroy River.

The seam which proved to be 12 feet thick was met with at a depth of 50 feet from the surface in strata which there seems strong geological reasons for believing to be of Upper Carboniferous Age.

An analysis of this coal, in the Survey Laboratory, was as follows:—

Moisture	..	..	..	..	8.87
Volatile hydrocarbons	..	..	..	..	29.73
Fixed carbon	..	..	..	..	33.99
Ash	..	..	..	..	27.41
					100.00

Calorific Value 7722 B.T.U.

A sample of the above coal was received from the owners of Liveringa Station and was found to consist of grey shale and thin bands of coal, the thickest being about half an inch. An analysis was made of some of the clean coal and this yielded the following percentages:—

Moisture	..	..	..	..	11.71
Volatile hydrocarbons	..	..	..	..	37.81
Fixed Carbon	..	..	..	..	36.92
Ash	..	..	..	..	13.56
					100.00

Considering the very large area which these Carboniferous Rocks occupy in Kimberley, there seem good reasons for believing that other seams than this exist.

11th August, 1911.

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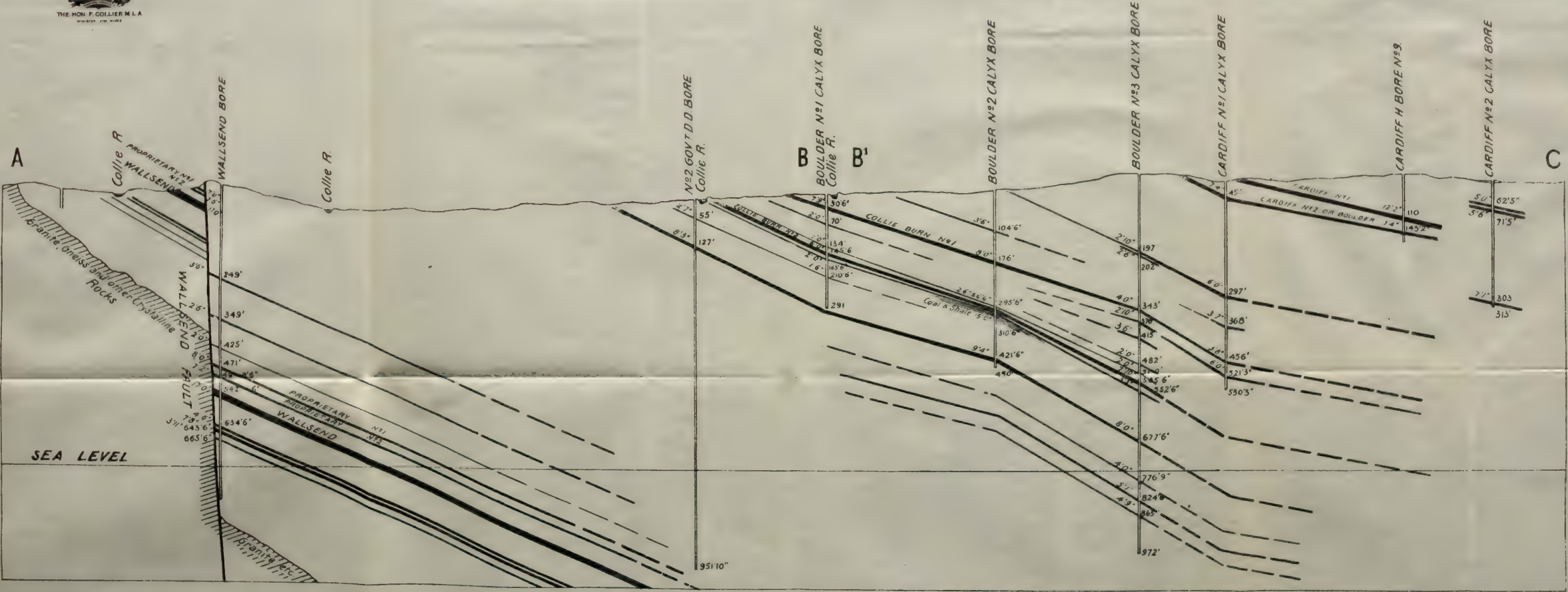
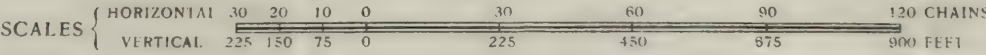
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COLLIE COALFIELD

LONGITUDINAL SECTION

A. B. FROM THE NORTHERN BOUNDARY OF PORTION 335 TO THE SOUTHERN BOUNDARY OF THE BARRIER RESERVE NORTH OF LEASE 47 AND B!C. FROM BOULDER N°1 CALYX BORE TO CARDIFF N°2 CALYX BORE



R. Logan Jack
Commissioner

53.—THE MINING GEOLOGY OF YERILLA, NORTH COOLGARDIE GOLDFIELD.

BY J. T. JUTSON.

(With three Plates, III., IV., V.)

CONTENTS.

	Page
Introduction	13
Previous Work	14
Topography and Vegetation	14
General Geology	15
1. Nature and Distribution of the Rocks	15
(a.) Basic	15
(b.) Intermediate	18
(c.) Acid	18
Granite	19
Aplite	19
Porphyries	20
Felsite	21
(d.) Laterite	22
2. Relations of the Rocks	22
3. The Lodes	23
4. Alluvial Deposits	27
The Mine Workings	28
Gold Yield	39
Water and Mining Timber	40
Future prospects of the Field	40
Summary	44

INTRODUCTION.

Yerilla is situated about 21 miles east-south-east of Kookynie, a mining town on the Kalgoorlie-Leonora railway; and has been a small mining centre for a fair number of years, apparently having been discovered soon after the first great rush to the Eastern Goldfields over 20 years ago. Yarri is about 40, and Edjudina about 50 miles respectively farther to the south-east. The regular means of communication between Yerilla and Kookynie are by a weekly coach and mail service. Yerilla is also connected by telegraph and telephone with Kookynie.

The area embraced in this report comprises a belt of country, which extends from the township of Yerilla north and east for about six miles, south for about four miles and west for about two miles. The accompanying geological sketch map on a scale of 40 chains to the inch (Plate V.), shows the geology of the area. The

small mining area immediately to the west of the township (which area includes the Yerilla King, Viola, Melba, and Queen of the Earth reefs, and is the most important strip) has been made the subject of a detailed survey on the scale of 10 chains to an inch (Plate III.) without, however, showing the whole of the shafts and other mine workings. The other proved auriferous belts to the north and south of Yerilla, and the belt at Mt. Catherine and its vicinity, having been examined in less detail, while the rest of the area has only been traversed in various directions.

Most of the old workings were inaccessible for examination, as they have long since ceased operations.

A State battery exists at Yerilla.

PREVIOUS WORK.

A brief reference was made to the geology of the Yerilla district by Mr. A. Gibb Maitland, the Government Geologist, in his report on the country between Edjudina and Yundamindera, published in 1903 as Bulletin No. 11 of the Geological Survey. Mr. Maitland notes (*inter alia*) the greenstones of the Catherine Range, and the intrusion of these greenstones by granite and porphyry dykes. He also remarks that greenstone schists (associated with bands of breccia, which may possibly be of volcanic origin), occur farther to the east, in the vicinity of Lake Raeside, and that these schists are traversed by diabase (?) dykes.

Mr. A. Montgomery, the State Mining Engineer, in his Annual Report for the year 1905 (pp. 95-97) briefly describes the principal reefs of the district, including the Viola, Melba, and Mt. Catherine. The Yerilla King reef had not been discovered.

TOPOGRAPHY AND VEGETATION.

The chief mining area of Yerilla to the west of the township, is situated on a broad, low ridge, which falls gradually away to the north to some extensive flats. The country generally is level, or broken only by some low "breakaways" of laterite, but a comparatively high belt of country exists between four and five miles to the south-east of the township. This belt comprises the Catherine Range, on which is a Trig. Station (W19); and it extends north-easterly for about two miles with a breadth of about a mile. This high land is part of an old plateau, which, however, has been dissected into a maze of steep ridges and gullies. The ridges are very stony, being covered with a creeping sheet of rock-waste, resulting from the breaking up of the rocks (chiefly fine-grained greenstones) of which the hills are composed. The gullies run out on all sides from this elevated mass, gradually losing their well-defined forms as they approach the surrounding plains.

Apart from the Catherine Range belt, there are few prominent hills or ridges in the district. Amongst those that exist, Mt. Cay (Trig. Station W11) which lies about two miles to the south-west of Yerilla township, forms a rather pronounced north-facing laterite bluff; and Mt. Catherine, to the north of Catherine Range, is a striking-looking hill of quartz, rising abruptly from the flat valley to the west of it. A fairly high ridge trends north-westerly on the western shore of Lake Raeside. This dry lake forms a striking feature in the landscape, but it is outside the area of this report.

In addition to the generally level areas that occur at the tops of the low breakaways of laterite previously referred to, there are extensive flats, two of which are that forming about four miles of the long mining belt west of Yerilla; and that commencing about three miles east of Yerilla and extending farther east for about two miles and in a north and south direction for some three miles. These flats carry comparatively little detritus.

The vegetation may be divided into three main types, viz., "Mulga" on the more elevated country; dwarfed shrubs of practically one type on the stony ridges; and salt-bush, bluebush, cotton bush, samphire, and other small plants on the lower flats.

GENERAL GEOLOGY.

1.—NATURE AND DISTRIBUTION OF THE ROCKS.

(a) *Basic.*

These occupy almost the entire area dealt with in this report. They are of very considerable diversity in structure and texture, but a detailed survey would be necessary to attempt to subdivide them into definite areas. The rocks as a whole may for the present be termed greenstones (using this term merely in a broad field sense, pending a microscopical examination of some of the rocks). They may be divided into massive and schistose, and the latter series will be termed schistose greenstones or merely schist, without implying that all these rocks are actually derived from the massive rocks or any one or more groups of the latter. The massive ones again may be divided into three groups, viz., coarse-grained porphyritic, and fine-grained.*

The relationship between these various groups has not been fully determined. Thus the schists may be (1) distinct in origin from the massive rocks—and perhaps derived from sedimentary or igneous rocks or from both—or (2) merely altered forms of one or more of the massive series, (3) partly the latter and partly of distinct origin. There is no direct field evidence one way or the other as to the origin of the whole of the schistose rocks;† and

* These do not include those at Lake Raeside, which are really outside the scope of this report. They are, however, briefly mentioned below.

† Near the Melba reef a fragment was picked up consisting almost wholly of loosely cemented quartz grains. The parent rock could not be identified *in situ*. Probably it is merely cemented surface detritus, and not an ancient sediment.

they have not been either chemically or microscopically examined. What little evidence was noticed, pointed to at least some of the schists being derived from the massive igneous rocks, in all probability chiefly from the fine-grained greenstones. This idea is based purely on the appearance of a gradual passage from one series into another. There is distinct evidence that the porphyritic type has been locally altered into a schist.

In the massive greenstone, a similar difficulty arises, as nothing conclusive has been observed to show whether the three groups are variations of one rock series formed at practically the same time, or whether they are distinct from one another. The outcrops of the fine-grained and porphyritic types point to a gradual change from one to the other, thus suggesting their identity of origin; but the relations of the coarse-grained series are obscure. All three groups are no doubt derived from gabbros or dolerites.

On the maps, therefore, all these rocks have simply been classed as greenstones, with some notes as to the localities of types.

The schists are usually very laminated, and highly decomposed at the surface, where they are often not much more than a ferruginous clay. At depth they appear to pass into chlorite and other related schists. The strike of the planes of schistosity varies considerably, but in the main auriferous belt it is fairly uniform, averaging about N10 deg. W. To the east of Yerilla, some of the rocks trend about north-west, while to the south, near the Catherine Range, such schistose rocks as occur are most irregular in their strike, the latter varying from east and west, through north-west and south-east, to north and south. The planes of the schists are sometimes vertical, but are often inclined, the predominant dip being to the east at angles varying from 45 deg. to 85 deg., the general probably being about 65 deg. The schists are widely distributed. They occur along the narrow mining north-north-west belt to the west of Yerilla. They are found also on the wide flat previously referred to, about three miles to the east of the same township. Some schistose rocks also occur in both the coarse-grained and fine-grained greenstones, but the outcrops are small, and the foliation planes lack uniformity of direction. Most of the quartz reefs of the district occur in the large belts of schists usually in low-lying country.

The massive greenstones are grey in colour, tough and dense. The fine-grained group forms the Catherine Range area and other ridges, and is much more widespread than the coarse-grained group. The latter outcrops in a rather prominent ridge about three miles east-south-east from Yerilla, and also in some ridges one and a-half to two miles west of the township.

These massive greenstones, of both the fine-grained and coarse-grained groups, are hard and project well above the general level of the country on account of their erosion-resisting powers, which in turn may be largely due to their having escaped extensive foliation. Few quartz veins occur in them, and thus there may be a connection between the distribution of the quartz veins and the relative height of the ground. In high ground there may be a few quartz veins, and in low ground many, the reason being that the rocks forming the high ground are massive, and consequently resist erosion; and prevent, by the absence of fissures, the introduction of quartz and other minerals. The rocks of the low ground, on the other hand, by reason of the planes of schistosity permitting a free circulation of meteoric waters, have been rapidly worn down, while the auriferous reefs have been introduced, the planes of the schists frequently acting as the channels of circulation and deposition of ore-bearing solutions.*

The two main groups of massive greenstones are usually homogenous in texture, but associated with these in various parts,† particularly with the fine-grained rocks, is the porphyritic type with phenocrysts of felspar crystals of varying size and number in a fine-grained ground-mass. For example, one specimen collected shows very numerous crystals up to 3/16 inch in size, while another has only a few scattered ones, which, however, reach a half-inch in length; and yet another has both small and comparatively few phenocrysts. As already pointed out, on field evidence alone, this group appears undoubtedly to be a phase of the fine-grained type, as the former may be seen gradually passing into the latter.

An interesting rock series occurs at the cliffs on the western side of Lake Raeside near the island, and at the island itself. The main mass of rocks consists of a fine-grained basic rock, highly schistose in places, and rather more massive in others. On the weathered surface, the rock frequently appears to be made up of pre-existing rock fragments, and suggesting its origin as a volcanic agglomerate, or as an ordinary breccia. A careful examination in the field, backed up by the microscope, however, is required to determine the nature of this rock, as some of the apparent fragments may be due to a peculiar weathering of the rock. At the island, similar rock occurs, but there are hundreds of circular and almond-shaped cavities, varying in size from one-eighth inch to four or five inches, which have been filled by calcite and quartz, obviously of secondary origin. (These minerals are now being removed again

* These remarks of course apply to the Yerilla area, and what is here noticed cannot by any means be accepted as a uniform condition elsewhere. In fact, the reverse is often (perhaps usually) found to be the case, as the introduction of quartz has enabled the ground to resist erosion, with the result that the lodes are in the ridges, as so often occurs in Western Australia.

† In one or two localities the three types occur together, and have the appearance of being variations of one another.

by the weather, leaving at the surface a vesicular rock.) The numerous small joints that traverse the rocks are likewise filled with secondary minerals. The rock is evidently the remains of an old lava-flow, the vesicles of which have been converted into amygdaloids, by the introduction of the secondary minerals. If this should be the case, it may ultimately throw light on the origin of other rocks of the district. It also strongly suggests that if the brecciated-looking rock be of undoubted fragmental origin, then it is probably a volcanic breccia, as already suggested by Mr. Maitland.

Intrusive into these amygdaloidal rocks are some small dykes of a hard fresh-looking black, rather fine-grained, basic rock, which has also been noticed by Mr. Maitland. Whether this dyke stone is younger than the intermediate and acid rocks to be now described cannot be stated, as no evidence is available.

It will be convenient to refer collectively to these rocks by the lake as the "Lake Raeside series of basic rocks."

(b) *Intermediate.*

The representative of this class occurs in a fairly extensive outcrop rising well above the general level of the country, about six miles to the east of Yerilla. Its western boundary is close to the edge of the area included in the geological sketch map. This rock at a distance resembles granite, but on inspection it is found to be free from quartz, and to be chiefly made up of felspar, with a ferro-magnesian mineral, probably hornblende. It is granitic in texture. The rock may be termed syenite. (This and other rock names are used as field terms and are subject to revision after microscopical examination.) The syenite is shown to be intrusive into greenstones by numerous tongues (at the south-western corner of the outcrop) of finer-grained rock—due to more rapid cooling—penetrating the greenstones. This tongue type, although undoubtedly a part of the same rock series as the syenite, appears from megascopic examination to be mainly a mixture of granular quartz and felspar.

The syenite is traversed by thin quartz veins along the vertical joint planes, but otherwise they do not occur, and the rock is of no economic value from a gold-bearing point of view. It would probably, however, make a handsome stone on being polished, but its inaccessibility, and the fact that it is rather closely jointed, will prevent its use for building or ornamental purposes.

(c) *Acid.*

These rocks may for field purposes be divided into granite, aplite, porphyry, and felsite. The granite occurs as small masses, while the other rocks are dykes, all being intrusive into the greenstones.

Granite.—Three small areas have been noticed, but it is probable that others also occur, as most of the country has only been examined in a general way. The principal area is just to the west of the town, where the chief mining belt is situated. It occurs as a small elliptical mass, having its longer measurement approximately north and south, and being surrounded by greenstones. The intrusion of the granite has evidently had some effect—either direct or indirect—in the distribution here of the auriferous quartz reefs. This question is later discussed.

Two other patches occur on the new road to Edjudina, the larger one being from two and a-half to three miles south-east of Yerilla, and the other close upon four miles from the same place. These are small intrusions into the greenstones similar to that close to the township. The rocks in the three areas are much decomposed, but they may be observed to consist chiefly of quartz and felspar, with a ferro-magnesian constituent. Biotite is abundant in the rock from the most southern (smallest) area.

The granites are practically massive throughout, the only exception being noticed along the junction of the granite and greenstone south of the West Melba reef. Here the granite is foliated perhaps for a few feet, but it soon passes into the ordinary massive form. This foliation is probably due to flow structure induced at the time of intrusion. It is evident from the general non-foliation of the granite, that the schists were formed before the intrusion of the granite, otherwise the latter, in the area west of Yerilla, could hardly have escaped extensive foliation. No dykes or veins connecting directly with any of the granite bosses can be traced, but there is little doubt that the various dykes to be presently described are genetically associated with these granitic rocks. In the Yerilla King mine, very thin veins of a fine grained, decomposed granite traverse the country, and as the mine is fairly close to the granite, these veins have doubtless originated from the rock mass.

Quartz reefs occur in the larger granite area to the south-east of the town, but they have not been worked, and it is doubtful whether they have been prospected.

Aplite.—This rock has been observed to the west of Catherine Range, near the south-western corner of lease 376R, as a series of short dykes, of a width from two to eight or ten feet, intrusive into the greenstones, which are here beginning to rise into ridges. The rock is massive, tough, of granitic texture, of pink colour, and practically undecomposed. It is composed of quartz and felspar with an occasional flake of mica, and occasional felspar phenocrysts. These dykes have an approximate west-north-west trend, but as others no doubt exist in the district, this cannot, without further examination, be considered as their dominant direction. So far as observed, they are not foliated, and they have not been traced into any granite mass; but they have doubtless been derived

from deeper-seated granitic rocks, of which the small areas now found at the surface form bosses.

Porphyries.—The porphyries form another series, which include both quartz and felspar-porphyries. They have been chiefly noticed by the writer in the Catherine Range area; near the south-western corner of lease 376R (west of Catherine Range) and further west on the flats; on the flat to the west of Mt. Catherine, close to but west of the main road; and about three quarters of a mile north-north-west of Mt. Catherine, immediately to the east of the main road, on a low hill of fine-grained greenstone. They would not average more than four feet in width, and a few chains in length. Their general trend appears to be close to east and west; thus that outcropping north-north-west of Mt. Catherine runs N55 deg. W., the two observed to the west of the hill just named strike N70 deg. W. and S85 deg. E., respectively, while of eleven noticed in a traverse for about two miles north-north-east from the Trig. Station on the Catherine Range, across the high dissected greenstone plateau, one had a strike of N40 deg. W., while the others ranged from N70 deg. W. to east and west, the mean being about N80 deg. W.*

Most of the rocks possess a fine-grained grey-coloured ground mass, in which lie the phenocrysts of quartz and felspar, with in some cases biotite. There is considerable variety in both the number and nature of the phenocrysts, and in places the porphyry becomes practically a granite-porphyry. Despite, however, these variations, these rocks apparently belong to the one series.

As illustrating this variety it may be mentioned, that in the traverse made from the Trig. Station of the Catherine Range, a change could be observed from a porphyry containing no felspar or mica phenocrysts, but possessing numerous ones of quartz attaining more than a quarter of an inch in size, to another porphyry in which quartz phenocrysts were practically entirely absent, while those of felspar were abundant. Another dyke possessed few phenocrysts, but those that occurred consisted of both quartz and felspar, the latter if anything being the more numerous. These examples show the gradations that may occur. In the rock north of Mt. Catherine, quartz, felspar, and biotite occur as phenocrysts in a very fine-grained ground-mass. The same feature is even more marked in the dyke west of Mt. Catherine, which is cut by a quartz reef. This rock may be described either as a porphyritic granite or a granite-porphyry, and it illustrates the transition from the normal granite, indicating that in all probability the dykes are merely tongues from the main granite areas. Confirmation of this must wait microscopical examination and chemical analysis, with perhaps more detailed work in the field. In this connection, however, an

* Acid dykes, other than the porphyries, may occur in the greenstones of the Catherine Range, but beyond some having a texture approaching granite, only porphyries were actually observed in the traverse made by the writer.

analysis of a felspar-porphry from the Catherine Range, made some years ago in the Geological Survey Laboratory by Mr. E. S. Simpson, the results of which appear in Mr. Maitland's Bulletin No. 11 (p. 7) may be quoted.

SiO ₂	..	..	..	..	..	..	70·82
CO ₂	..	..	..	..	..	..	·40
P ₂ O ₅	..	..	..	..	..	..	trace
TiO ₂	..	..	..	..	..	..	·35
H ₂ O+	..	..	..	..	..	..	·27
Na ₂ O	..	..	..	..	..	..	5·57
K ₂ O	..	..	..	..	..	..	1·94
MgO	..	..	..	..	..	..	·87
CaO	..	..	..	..	..	..	2·20
MnO	..	..	..	..	..	..	·13
FeO	..	..	..	..	..	..	1·73
Fe ₂ O ₃	..	..	..	..	..	..	·51
Al ₂ O ₃	..	..	..	..	..	..	15·56
FeS ₂	..	..	..	..	..	..	·20
H ₂ O—	..	..	..	..	..	..	·05
							100·60

The high percentage of silica places this rock in the acid division, and strengthens the suggestion of its relation to the granite.

All the observed porphyries are intrusive into the greenstones, and except in one case they are not foliated. This exception occurs just to the west of the south-western corner of lease 376R (west of Catherine Range) where the rocks outcrop on a flat, and are highly foliated with a strike of about N55 deg. W. About three chains to the north, another outcrop occurs, the rocks here trending S60 deg. W., and then swinging round to N55 deg. W. A specimen from the latter outcrop shows that along the foliation planes, a black mineral (probably biotite) has developed in very minute particles. The phenocrysts are practically all felspar, and they do not appear to have suffered from the agency that brought about the general foliation of the rock. They are unbroken and not elongated, while the lines of minute biotite (?) do not bend round them, but run straight against the crystals, and commence again on the opposite sides.

One of the porphyry dykes to the west of Mt. Catherine is cut by a quartz reef trending north and south. The reef is therefore later than the dyke, and if all the main reefs are of the same age they must be later than the dykes.

Neither the aplite nor the porphyry in the Yerilla district appears to have exercised any influence in the distribution of gold, the auriferous quartz reefs generally being quite dissociated from these acid dykes.

Felsite.—An exceedingly fine-grained rock of an evidently acid nature, which may provisionally be classed as a felsite, occurs as a dyke or a series of dykes intrusive into greenstones in the rather

high ridge to the west of, but close to Lake Raeside. This area, however, is outside the scope of this report.

(d) *Laterite.*

This rock occurs fairly abundantly in the Yerilla district, capping isolated hills and "low breakaways." In one of the latter, about three miles east-south-east from Yerilla, it is nine feet thick, but it is usually much less than this. It caps the basic rocks, and has not been noticed on the granite, the reason being the greater abundance of iron in the former than in the latter. Its detritus is spread more or less over the whole country.

2.—RELATIONS OF THE ROCKS.

The relations between the various rocks have been to some extent already indicated under their descriptions, but they may be more conveniently summarised here.

The basic rocks comprising the greenstones and schists appear as a whole to be the oldest rocks, but as between the divisions of this basic group—fine-grained, coarse-grained, and porphyritic massive greenstones, and the schists—the evidence as to their relative age is quite indefinite? What is available points to at least some of the schists being derived from the massive, fine-grained greenstones, to the massive porphyritic type being only a variation of the fine-grained type, and to some schists having locally originated from the massive porphyritic greenstone. The amygdaloidal rocks at Lake Raeside, together with the accompanying basic dykes are excluded from consideration here.

The intermediate and acid rocks are younger than and intrusive into the greenstones. Amongst their component groups, the aplites, porphyries and felsites are probably derived from and perhaps nearly contemporaneous with the granite intrusions. No evidence has been collected to show in what order the acid dykes have been intruded, as no two groups have been seen in juxtaposition. As regards the syenite, it may have been derived from the same magma as the granite, and this is supported to some extent by the apparently more acid nature of one of the tongues from the main mass as noted above; but here again the field evidence is quite deficient as to whether the granite or the syenite was first intruded into the greenstones. Detailed work may throw some light on this question.

The quartz reefs (or at least some of them) have been formed last. They occur in both greenstones and granite, and one has been observed to cut through a porphyry dyke. In the brecciated syenite-quartz lode described under the lodes, a syenite dyke has been crushed and broken, and later the quartz has filled the cavities.

3. THE LODES.

Except for the possible lode-formation at the "Queen of the Earth," all the lodes of the district hitherto discovered are quartz reefs. The latter are fairly widespread, but the only well-defined belt is the narrow one running from about four miles south of Yerilla to about six miles to the north-north-west of the township. This main belt passes the township on the western side of the latter. This area has not been proved to be continuously gold-bearing, and in addition, at the extreme northern and southern ends, there is practically only one line of reef. The chief portion extends for about three miles north of the township, and for about a mile to the south, with an average width of about three quarters of a mile.

The rocks of the main belt are chiefly schistose greenstones, having a persistent strike a few degrees west of north. The planes of the schists are sometimes vertical, but often inclined, the inclination being most frequently to the east at an angle varying from 45 deg. to 85 deg., but commonly about 65 deg.

The most important reefs of the district (those just to the west of the township) occur in the main belt mentioned. They are generally approximately north and south in their trend, including in this category the Yerilla King and its southern extension, the Queen of the Earth, the Melba, and the West Melba. The Melba and the Yerilla King dip to the west, others to the east. An important east and west reef with a northerly dip is the Viola. These reefs, as already pointed out, occur in either granite or greenstone, but close to the junction of these rocks. This may have some significance, and the matter is discussed in the part treating of the future prospects of the field. The reefs in the remainder of the main belt dip mostly to the east.

There are no other known well-defined auriferous belts in the district, and such reefs as occur are scattered and irregular in their strikes. The principal reef area so far discovered (outside of the main north-north-west belt at Yerilla) comprises Mt. Catherine, and the country to the north and to the south-west of this hill. The trends of the reefs in this locality vary from east-north-east, through north-east-north, to north-west, the dips, however, being as a rule, towards the east, the exact direction varying of course according to the strike. A moderate number of reefs occur on the wide flat, commencing about three miles to the east of Yerilla, and some have been worked to shallow depths. The majority, however, are apparently non-auriferous, as no work has been done upon them.

Large quartz "blows" are not very common throughout the district, but several occur, the most prominent being that forming Mt. Catherine, a huge lenticular mass of quartz rising perhaps 30 to 40 feet above the surrounding country. Another very notice-

able reef is that in the old Daisy (?) lease, No. 4152, about half a mile north of Mt. Catherine. Other small "blows" occur within a mile to the north-west of Mt. Catherine, while on the wide flat previously referred to, to the east of Yerilla, numerous reefs rise three and four feet from the surface. The "blows" in this district as elsewhere, do not appear usually to be payably auriferous.

Many reefs lie between the planes of the schists, and hence the fissures such reefs occupy tend to be irregular, and to affect the continuance in length and depth of the reefs. Some of the latter, however, cut across the planes of the schists—of which the "blow" forming Mt. Catherine is an example—while others occupy fissures in massive greenstone (the latter usually, however, being within a schistose belt) or in granite. Examples of the last mentioned are the Yerilla King and Melba reefs, which are in greenstone and granite respectively. The distinctive belts of massive greenstones carry few reefs, and these do not appear to be payable.

The thickness of the reefs varies from that forming Mt. Catherine—which is about 30 feet in the thickest part—to a few inches. The great majority are probably under three feet in thickness, and an average would perhaps be about a foot.

No faulting (except on a very small scale) has been observed in the reefs, which are generally followed without difficulty. Even where blanks occur, the channel is usually well-defined, and so the reef can be located again.

A feature in connection with the Yerilla King reef, not noticed elsewhere in the district, is its tendency to form rolls (see transverse section of the mine (Plate IV.)). The reef dips to the west, but occasionally it bends back to the east, and then gradually curves round again to the normal dip, forming a rough semicircle in its change from and to such dip. Frequently the reef suddenly thins at the roll to a few inches (even in places, it is said, being absent), while at both ends of the roll in the normal dip, it may be from 20 to 24 inches thick. The reef is only bent a few feet out of its course by one of these rolls. More than one occur, and the most prominent is stated to pitch north from the 60 feet level of the adjoining lease on the south, to about the 200 feet level, near the main shaft. Values are said to become low at and near these rolls. A point of interest is whether the latter were formed before or after the precipitation of the quartz in the fissures. The fissures are, so far as observed by the writer, unbroken, and the strong hanging wall follows round the curve of the lode. The formation of the rolls has evidently reduced the width between the walls, and if the quartz were there on such such formation, it should be crushed and broken; but the quartz perceived in the rolls was just as free from crushing as that in the normal fissure. The rolls may therefore on present evidence be regarded as formed in the fissures before the

quartz. They are likely to die out in depth, but may of course continue for the comparatively shallow depth that the mine may be worked, unless they die out owing to a change of the country from greenstones to granite.

The quartz is mostly uniform in character, and calls for no special remarks. It is generally white and dense (but a few vughs occur) with little mineral showing. At the old Daisy (?) lease, No. 4152, some of the quartz has a bluish tinge. In one or two places, the quartz was mixed with the country (greenstone), in such a way as to suggest that the former was gradually replacing the latter.

The minerals include sericite, galena, and pyrites. The east and west Viola reef has had many of its cracks and casings lined with an oxide of manganese. A "bar" of the latter, about three inches thick, may be seen cutting across the reef at a depth of about 90 vertical feet, below the surface. The manganese is clearly a later deposit than the quartz. Molybdenite has been identified in the Melba reef, which occurs in granite, but the amount was just sufficient to recognise it.

The greatest depth of working is apparently at the Yerilla King, where a main shaft is 200 feet deep, vertical. Below this depth, winzes extend for about a further 20 feet on the underlay. Some of the old workings in the various leases have gone below water level, but the depths are not known, and these workings are now inaccessible. The Yerilla King mine, however, has probably reached the greatest depth.

As regards their relative age, the reefs occur in the greenstone and granite, and one cuts a porphyry dyke, so that the reefs are probably all later than the whole of the rock-formations of the field.* An interesting point, however, is whether two or more sets of quartz reefs occur. Outside the main belt to the west of Yerilla, the reefs are very irregular in their strikes, so that only the main belt can be considered. In this area, the great majority trend north and south (approximately), but the Viola is a pronounced east and west reef with a northerly dip. (Other more or less east and west ones occur south of the Viola and north of the Melba, but as they are short and irregular, they may be neglected in this discussion.) Thus one strong fissure is almost at right angles to many others, and no evidence is available from their contained reefs as to whether they are all contemporaneous or of different age. Some light, however, may be thrown on the question by the porphyry dykes and reefs in the Mt. Catherine area. Here the dykes are usually east and west, and some strong-looking reefs are north and south. One of the latter cuts a porphyry dyke, so that it is clear it is younger than the dyke, and, therefore, in all probability that its fissure is of later date than that of the dyke. By

*The Lake Raeside series of basic rocks are not here considered.

analogy, therefore, it is possible that the Yerilla King fissure is later than that of the Viola, and hence that if the reefs are of different ages, the Yerilla King is perhaps younger, and should cut the Viola, unless the fissure of the latter stops west of the Yerilla King. It is impossible to settle the point on the available evidence; but it is worth bearing in mind that the Viola reef may extend to the east of the Yerilla King, and that as the former has yielded a fair amount of gold, its continuation eastward (if it exist) may do likewise.

Some of the reefs will no doubt ultimately be found to pass at depth from greenstones into granite and *vice versa*. Thus of the former, the Yerilla King and the Viola are probable examples, and of the latter the Melba may be an instance. The reefs, as a whole, appear to have been formed after the intrusion of the granite, so that a reef is not likely to cease on meeting different country. The matter is referred to again in the descriptions of the reefs just mentioned, and in some detail in that of the Yerilla King.

Summing up the characters of the quartz lodes, they may be stated to be usually in the form of reefs with rapid changes in their thickness, and with blanks. They are practically free from faulting or other disturbance (except in the case of the Yerilla King which has a series of rolls through the reef). They frequently lie between the planes of schistosity of the rocks, and so will tend to be irregular; but there are apparently true fissures in both the greenstones and granite, which indicate some permanence of their contained reefs at depth.

There is a possible lode-formation at the Queen of the Earth. It consists of highly sheared greenstones, but no particulars are available as to what values it carried.

An interesting lode, that, however, was apparently unpayable, occurs in one of the tongues of the large syenite mass well to the east of Yerilla. This tongue and the adjacent greenstone country has been crushed and reduced to a breccia for a thickness of about three feet. Between the interspaces of the rock fragments, quartz has been deposited (and possibly also in part has replaced the rock) forming a lode which may be described as a syenite-quartz lode. It strikes about east and west, and dips to the north at an angle of about 15 deg. Two shallow holes have been sunk on it.

So far as could be ascertained, the gold in the quartz reefs is generally very fine, and practically all of it is free. Except in the Yerilla King reef, the gold of which occurs in a shoot pitching north, the writer has not been able to definitely learn if there be any dominant pitch in the shoots.

As noted above, aplite and porphyry dykes do not appear to have any influence in this district in the distribution of gold.

The water level of the lodes is about 100 feet.

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4. ALLUVIAL DEPOSITS.

These may be divided into surface and deep. The former occur as a small patch north-west of the Yerilla King reef, and in similar patches in some other parts, but taken altogether, the surface alluvial deposits appear to be very scarce. They have not been mapped.

The deep alluvial deposit occurs as a deep lead north of the Viola and west (mainly) of the Yerilla King reefs. The latter reef was discovered when the deep lead at its eastern end was bottomed, at a reputed depth of about 20 feet. A number of shafts have been sunk on the lead, but it is reported that from only one or two was any gold obtained. As indicated by the shafts, the "lead" trends about west-north-west and east-south-east (the actual direction of fall not being known) for about eight or nine chains, and has a width of from two to three chains, with a depth of generally from 15 to 20 feet. This appears to be the depth right across and along the lead, no defined "gutter" having been discovered. The deposits forming the lead rest upon greenstone in its eastern portion, but upon decomposed granite in its western part. Alluvial workings of the same depth occur, running north-north-east over a width of a chain or more for a few chains towards the western end of the workings of the main portion; but the two parts do not meet, so that it cannot definitely be said that one is a tributary of the other.

It seems very probable that this lead occupies a closed basin. The bedrock comes right to the surface to the south, to the west, to the north (in parts), and perhaps to the east. In the last direction, a covering of laterite prevents this point being determined; and on the north, the surface falls away and a covering of recent wash prevents detection of the underlying material. If the lead has an outlet, it is probably to the north, but if it be bounded by "live" rock, then it is important for the light it throws on the deep leads in general.

The nature of the deposits forming the lead is best observed in its western portion, that is on the granite, where most of the work has been done. From specimens on the dumps, the wash varied from sand of uniform size to a mixture of sand and individual quartz fragments, the latter varying from a quarter of an inch to four inches in size. All the wash is loosely cemented together. The sand has evidently been derived from the underlying granite, and the quartz fragments from adjacent reefs. These fragments are all very angular, or at most some might be termed sub-angular, as the corners are somewhat blunted. There is certainly no evidence from the rock fragments of any great water action, but the sections disclosed by the shafts require examination to give information as to stratification and other matters. No fragments other than quartz were noticed in the wash.

An alluvial deposit at least 12 feet thick (shown by a shaft) was noticed in one of the flat watercourses, a little north of Mt. Catherine, but its relations could not be determined.

THE MINE WORKINGS.

YERILLA KING, G.M.L. 851R.—The Yerilla King reef was one of the latest discoveries in the Yerilla district, the reason for its non-detection earlier being that it was covered by a deep lead to a depth of perhaps 20 feet. The lead was being worked, and the reef was found at the bottom. This is another instance of how lodes are concealed in Western Australia.

The Golden Ridge Company recently had an option over this mine, and some developmental work, the writer understands, was done by the company. The option, however, was not exercised. The mine at present belongs to a syndicate.

Apart from three short winzes, this mine has only been worked to a vertical depth of 200 feet. There are four levels, viz.:—75 feet,* 100 feet, 130 feet, and 200 feet, all measured from the vertical. A vertical main shaft has been sunk 200 feet, where the reef is cut, and from which the 200-foot level has been driven. Two other vertical shafts also connect directly with the main workings, one at 100 feet level, connecting with the 100-foot level, and the other at 75 feet with the 75-foot level. The accompanying plan (Plate IV.), which is based upon a rough survey of the mine, shows the trends and lengths of the various levels, so far as could be examined, but the levels are really longer than shown, but were not able to be fully seen on account of falls of earth, mullocking up, etc. For instance, all the levels have been stated to have been driven to the southern boundary of the lease. From the 200-foot level, three short winzes have been sunk on the reef, one north of the main shaft 16 feet deep, and the others south of such shaft, both stated to be 20 feet deep, but this the writer could not verify, as they had both been filled at the time of examination. The mine has no battery, the crushing being done at the State battery.

The country is greenstone,† much decomposed to the 130-foot level, and considerably altered at the 200-foot level, where, however, it can only be seen close to the reef. The rock is usually massive, but somewhat minutely jointed. In places, however, close to the lode, and particularly in the ore channel, where blanks occur, the greenstone is highly schistose, the strike and dip of its schistosity planes being parallel to the general strike and dip of the reef.

* The depth of this level is irregular, but as it is connected with a vertical shaft 75 feet from the surface it may be referred to as the 75-foot level.

† A few water-worn pebbles of greenstone were noted by the writer on the dump of the mine close to where the pumped water splashed on reaching the surface. No conglomerates have been seen in the mine or on the surface, and the origin of the pebbles is unknown.

Between the 200 and 130 feet levels, some nearly vertical veins of a white decomposed fine-grained granite cut through the greenstones. They are from one and a half to three inches thick, and occur on the footwall side of the reef which were observed, was not penetrated by them. They were said to exist elsewhere in the mine, and they, no doubt, represent tongues from the main body of granite to the west.

So far as could be seen throughout the mine, the hanging wall is strong, smooth, and well-defined, giving the appearance of permanence, but the footwall is much more irregular.

As regards the reef, so much has been stoped out, and so much timbering has been done, that it could not be seen in very many places. In addition, falls of earth had occurred that blocked examination. The reef had a general strike of about north and south, but slightly oscillates to the east and to the west of this direction. It dips to the west generally at a moderate angle, and it averages about 45 deg. The dip varies in amount in consequence of the rather flat rolls which occur in it. These are described fully below.

The thickness of the reef varies from a few inches up to three feet and often changes rapidly. Apart from actual blanks, its average might be about a foot, but it is impossible to give anything definite as to this. In places, it dies out altogether and thus blanks occur for varying distances. But although the reef may be lost for a time, the ore-channel is generally well marked, and is easily followed as a rule, so that there is not much difficulty in again locating the reef. The want of continuity, however, often causes a fair amount of dead work, so that unless the reef is fairly payable, the search for its continuation cannot, for financial reasons, be maintained.

In places, the reef may be dipping westerly at a moderately high angle, when it will suddenly bend towards the east, and then gradually swing back to the west, curving all the way, thus constituting a distinct roll or open flat fold in the reef. This feature is illustrated in the cross section of the mine accompanying this report. (Plate IV.). As observed, the reef in the roll is often much thinner (and at times said to be absent) than in the more regularly dipping part, the latter at times being about two feet thick, while the former may be only four or six inches or less. The question of the formation of the rolls either before or after the precipitation of the quartz has been discussed in the account of the lodes generally, and the inference is there drawn that the rolls in the fissure probably occurred before the quartz appeared.

One of the rolls referred to is well seen in the No. 1 Winze South, a few feet above the 200 feet level. This is stated to be traceable southward through the mine, but steadily rising in that

direction, and passing into the next lease, where it is met at the 60-foot level. On account of the stoping, this could not be traced, but the roll occurs at the 60-foot level of the adjoining lease as stated. This means, if correct, that the roll has a strong pitch northward, and as the pay-shoot pitches in the same direction (but not necessarily at the same angle), this roll may have had some influence in the distribution of the gold. A pronounced roll can be seen along the 200-foot level south from the No. 1 Winze South, and this one appears to be practically horizontal, and hence probably merges northward in the strong roll just mentioned.

North of No. 1 Winze North, in the 200-foot level, another roll may be seen, but the relation of this to the others is not clear. A roll is said to occur above the 130-foot level, just above the shallow winze, sunk towards the end of the south drive, but its position was not accessible. It must be another roll, as it is apparently too deep from the surface to be the long northward-pitching roll already noted. It has, therefore, been shown on the cross section. Another peculiar roll has been traced from the No. 4 Rise (towards the southern end of the workings). The reef when traced upward gives out, both vertically and horizontally (the latter southward), ending in a short curving line, approaching a half dome in form.

So comparatively little of the actual reef could be seen that no detailed description of its occurrence can be given. It may be mentioned, however, that along the south drive of the 200-foot level, it becomes very thin, and has a blank. North, however, of the No. 1 Winze South to about 40 or 50 feet north of No. 2 Winze North, the reef (at the 200-foot level) is, on the whole, well-defined with an average thickness of about two feet. In the winze north of the main shaft sunk from the 200-foot level to 16 feet on the underlay, the reef is about 20 inches thick at the top, and three feet at the bottom. At the end of the north drive of the same level there is a blank, and the reef has not yet been picked up again, but the ore-channel is well defined, and there is a fair amount of water coming through it. At the end of the north drive of the 130-foot level, the reef had also died out, but further driving, since the inspection, was stated to have located the reef again.

The two winzes south of the main shaft from the 200-foot level, and stated to have been sunk about 20 feet on the underlay, had been filled up, so were inaccessible for inspection.

According to the information supplied to the writer, most of the ground above the 200-foot level has been stoped out; some ground, however, being left above this level at its southern end.

The shoot of gold pitches to the north. The gold itself must be very fine and is little associated with other minerals. So far as known to the writer, all the gold has been free.

The water level of the mine is about 120 feet, but the flow of water is only moderate in amount.

The official returns show that to the end of April, 1914, the yield from the Yerilla King was 3,656.03 fine ozs. from 4,925.50 tons, an average of 0.74 oz. per ton. For May, June and July, the following returns have been kindly supplied by the owners:— 836.25 tons for 655.15 fine ozs. These, with the official figures, make a total yield to the end of July of 4,311.18 fine ozs. from 5,761.75 tons, which gives an average yield per ton of 0.75 fine ozs.

At the time of writing, the mine has been closed down, it may be only temporarily. It is to be regretted that this has occurred, as the return, as a whole, has been a very fair one, as returns go nowadays, although, of course, there were probably comparatively poor portions. The proving that this mine was payable to a reasonable depth would not only have been of direct benefit to the district, but would have been of indirect benefit in stimulating prospecting and in the trial of other reefs to fair depths.

Although the reef has blanks and pinches in places, yet the fissure is strong and well-defined, and there is no reason to think that the reef will not live to a reasonable mining depth, with, no doubt, the same draw-backs in the way of blanks and rolls (the latter possibly, however, dying out.) It, therefore, in view of this and of the general return, seems worthy of a further trial by deeper sinking, but of course it must be borne in mind that the country will become harder and the expense generally greater. There is also the possibility of the reef passing out of the greenstone into the adjacent granite to the west, as the dip of the reef is to the west. The granite has been intruded into the greenstones, and these intrusive masses generally widen from the surface downwards, so that if this happens in the present case, the granite will increase in width towards the east. Running a section across the Yerilla King reef, a little south of the main shaft, through the nearest point of the granite, and allowing only for a moderately increasing width of granite at depth, the reef on its present underlay, and along the line of section, would meet the granite at about 300 feet vertical. If the boundary of the granite were practically vertical, the reef would reach the granite at about 400 feet; and if the granite fell away to the west, the depth would be still greater; or according to the angle of inclination of the granite, the reef may not cut the granite at all, but this seems unlikely. (These depths are, of course, very approximate, and apply to the nearest point of the granite. As the eastern boundary of the latter runs from this point north-west and south-west respectively, the reef, north and south of the section line, may reach the granite at greater depths than those mentioned above).

On the question whether the granite would cut the reef off or not, provided the fissure and the reef were not formed until after

the intrusion of the granite, the former should pass into the latter, as the ore channel appears to occupy a true fissure, which would cut both greenstones and granite; and in the latter, the rolls may die out. If the fissure were formed before the granite, the reef would not exist in the latter, and the rolls may be due to pressure from the granite on its intrusion. If the quartz were formed before the granite, the reef must suddenly stop at the granitic junction. The general evidence of the district, however, points to the fissures and quartz being formed after the intrusion of the granite, so that if the reef meets this rock, it may be reasonably expected to pass into it.

There has practically been no test of the mine below 200 feet (except by the three short winzes sunk below that depth), although almost all the ground above that level has been stoped out. Want of capital has evidently been the cause of insufficient developmental work being carried out during the extraction of the payable ore, and this is a matter of much regret. The reef, however, is probably too small for most companies. Its most suitable method of exploitation would be by a working syndicate, or perhaps by a small company.

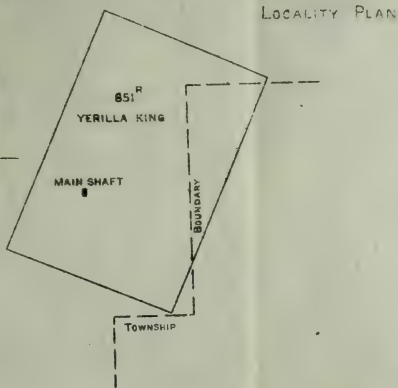
It might be noted if the reef maintains the same angle of inclination below the 200 feet level as above it, that if worked north of the main shaft, a vertical depth of about 400 feet would see it pass beyond the western boundary of the lease.

YERILLA KING (SOUTHERN EXTENSION), G.M.L. 693R.—This southern extension of the Yerilla King reef is referred to in the district as the Viola, but this was the name given to the east and west reef which runs westward through lease 693R into lease 684R, and it seems best to keep to the old name for the east and west reef, and describe the north and south reef as the Yerilla King Southern Extension.

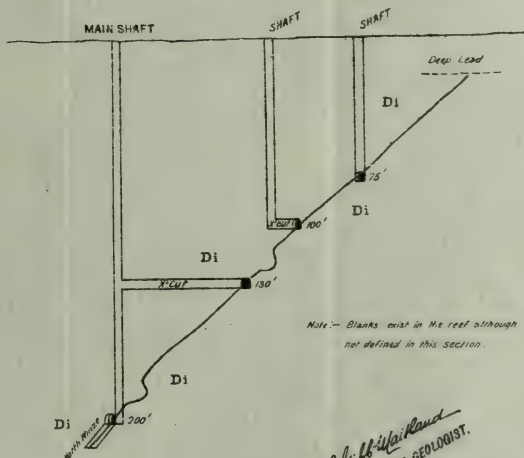
This reef has been worked by different parties, and a good deal has been stoped out. There are three levels, 60 feet, 130 feet, and 150 feet (all measured on the vertical). Two vertical shafts connect some of the levels, one, the whip shaft, being 150 feet deep, connecting the 150 feet and 130 feet levels, and the other, 60 feet deep, connecting with the level of the same depth.

The north drive in the 150 feet level has been driven for about 40 feet, but no stoping has taken place, as there are only a few inches of a mixture of quartz and ironstone showing. The south drive is about 40 feet long, and appears to have been stoped out above fairly well, so little of the reef can be seen. At the end of the drive there is a winze down about 20 feet (vertical), and this is the greatest depth of the workings. The reef in the winzes at the top is thin, and gradually dies out, but near the bottom it commences again, and reaches a thickness of 10 inches. In view of the

A graphical scale bar labeled "Scale of Feet." with markings at 0, 100, and 200 feet.



TRANSVERSE SECTION.



Note:— Blanks exist in the reef although not defined in this section.

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C B Anderson, del.

12

YENICK & SONS N. Y.

mode of occurrence of the reef generally, it is unlikely that this portion will continue to thicken.

The 130 feet level is connected with the whip shaft by a cross-cut, about 15 feet long. A winze is continuous with that mentioned in the 150 feet level. From the whip shaft to a pass, about 70 feet south (connecting with the 60 feet level), the ground appears to be practically all stoped out up to the 60 feet level. Beyond the pass the level continues south for over 100 feet; and the reef becomes thin and eventually dies out. The north drive is about 50 feet long, and hardly any reef appears to have existed here, but from between about 10 and 40 feet above the level, it is said to have been stoped out. The reef above this again was apparently not payable. At the end of the drive a rise connects with the 60 feet level, and the reef here can be seen thickening as it rises. In a pass about 10 feet north from the cross-cut connecting with the whip shaft, the reef can be noticed in places. It varies in thickness from six to 21 inches.

At the 60 feet level, which is not connected with the main (whip) shaft, some stoping above and below has been done. One of the rolls described in connection with the Yerilla King reef is well seen here. It may be the continuation of the northward-pitching one mentioned in the description of the Yerilla King Mine.

Speaking generally, the reef so far as could be seen, is not more than two feet thick and is often less. It dies out in places, leaving a blank. Its general strike is about north and south, and its dip westerly at an average of about 40 deg. or 45 deg. It is in fact very similar to that observed in the Yerilla King lease, of which it is a continuation.

The country is decomposed to a brown clay, with patches of white kaolin-like material. It is sometimes schistose, and, no doubt, represents a decomposed greenstone.

The gold is said to be all free and galena to be common. Some pyrites was noticed. The shoot pitches to the north, and, no doubt, forms part of that in the Yerilla King lease.

The yield from this reef cannot be given as the returns include various reefs in two leases.

VIOLA REEF, G.M.LS. (752R) AND 684R.—This is the original east and west Viola. Its western extension has also been referred to as the Yerilla Central, but the latter name belongs to the roughly parallel reef a few chains to the south, which runs through leases 684R and 884R. The name "Viola" will be retained for the whole of the reef passing from lease 693R into lease 684R.

At the time that the State Mining Engineer wrote his report on Yerilla in 1905, this reef was a recent discovery. The lateness of

this discovery was probably due to the thick cap of ironstone cement occurring here, being as much as four feet thick in some parts.

Many of the workings have fallen in, and as the main shaft, 150 feet deep, was inaccessible, not very much could be seen, but the 80 and 100 feet levels were examined as much as possible from a vertical shaft 80 feet deep.

There are three levels, 80 feet, 100 feet and 150 feet vertical. At the 80-foot and 100-foot levels the reef is as much as six feet thick and usually three to four feet. Near the shaft descended, however, it is thin and appears to split into stringers, but to the east and west, it is thick as mentioned above. Its strike is about east and west, and its dip northerly at an angle of about 35 deg. or 40 deg. Most of the workings are to the west of the 80 feet shaft, a fair amount of stoping having been done in that direction. To the east a little of the reef has been taken out, but there is no filling.

The reef is white and solid in places with none or but little oxide of manganese in the form of thin streaks. In other parts irregular veins of manganese from one-eighth inch to three inches in thickness traverse the quartz reef and are clearly later than the latter. The quartz in places appears to be crushed and sugary, and running through it are irregular seams of kaolin of widths from a streak to perhaps one and a half inches. In some cases both the manganese and kaolin cut the reef in a series of roughly parallel diagonal lines. One rather striking "bar" of manganese was noticed at about 90 feet deep. It was over three inches thick, and of solid manganese oxide. Its strike was parallel to that of the reef, but it was dipping across the latter, that is at right angles to the dip of the reef. It could be traced for at least eight feet in length. Good values were said to be often obtained near the manganese veins. The gold from the reef is supposed to contain much silver.

The country is decomposed greenstone, and the water level, according to Mr. Montgomery, is 101 feet.

Owing to this reef dipping to the north and granite outcropping in that direction, it is quite possible that the reef will pass into the granite at a moderate depth, but the ore-channel seems strong, and this change of country will not in all probability affect it.

The yield from this reef cannot be given, as other leases and reefs are included in the returns.

MELBA (formerly Lady Ailsa) and WEST MELBA REEFS.—The Melba reef has been opened a little at the surface and several vertical shafts have been sunk to cut it. There is also one main underlay shaft. In places the reef outcrops rather prominently at the surface, and is up to three feet in thickness, but its average is probably about a foot. In its southern portion its strike is about north and south, but at its northern end it runs north-

easterly. It dips westerly, at an angle of about 45 deg. Underground it could be examined in places down to about 100 feet. A moderate amount of stoping seems to have taken place. The reef below is generally about nine inches thick, sometimes a little less, and sometimes it reaches 18 inches. It is fairly straight and regular, but in places small faults occur, and elsewhere there are blanks, but these are apparently short. Two, three or four distinct veins close together were noticed in places, all apparently in one fissure. They may join at depth. At the northern end, the hanging wall is good, but in the south it is not so well defined. The foot-wall is more irregular. The fissure appears to be strong.

The country is decomposed granite with hardly any foliation, except just occasionally close to the lode. The ground stands well as a rule.

This reef is fairly close to the junction of the granite and the greenstones on the west, and it is a question whether it will pass into the greenstones. If the western face of the granite be vertical or inclined towards the east, the reef will probably do so, but as an igneous intrusion (here the granite) generally widens as it descends, it is an open question whether the reef will remain in the granite or pass into the greenstones. The section across the reef allows only a moderate falling away of the granite to the west at depth, and therefore, shows the reef passing into the greenstones. A reef to the west is dipping easterly, and it is just possible the two reefs may meet at depth, and if so good values may be obtained.

No water was in the workings, which were idle.

The West Melba reef lies a little to the west of the main (west-dipping) Melba reef. There is an open-cut, and some vertical shafts to the east of the reef. The latter strikes about north and south, and dips to the east at a moderate angle. The country is granite.

NEW WESTWARD HO G.M.L. 1067R. NEW LEASES 1001R.—The workings include several shafts. The deepest is an underlay one about 130 feet deep. There is another shaft to the north about 70 feet deep. This was descended, and from a drive south, the main shaft was used to reach the 130 feet level.

There are three accessible levels, 70 feet, 100 feet, and 130 feet. At the 70 feet level, the south drive to the main shaft is about 30 or 40 feet long. Some stoping has been done here and the principal vein, where seen, is about 10 inches thick. Other thin veins occur, and they, with the kaolin they intersect, form a lode between the decomposed greenstone walls. Unfortunately, however, the kaolin appears to carry no values.

At the 130 feet level, the south drive was only about 15 feet long, and the quartz vein was thin, ultimately dying out in fairly hard schistose greenstone. The north drive extended 100 feet from

the main shaft to a pass which connected with the 100 feet level. It was stated that the drive continued farther south for about 40 feet, but it was mullocked up. Practically none of the lode could be seen on account of the stoping towards the 100 feet level. A little underhand stoping had also been done. The writer was informed that the lode along the 130 feet level, consisting of quartz veins and kaolin (but mainly quartz veins), was in places five feet wide. The country at this level was schistose greenstone, much decomposed, but becoming harder at depth.

At the 100 feet level, some driving north and south of the pass mentioned had been done; to the south about 20 feet, partly through old workings, to a point where the drive had been blocked. The north drive was 25 feet long. The lode at this level consists of a principal vein, not more than eight inches wide, with subordinate veins, in kaolin. No overhead stoping had been done here.

The country at this level is schistose decomposed greenstone, but on the footwall a very coarse-grained greenstone occurred. It was highly schistose in some parts, and appeared less basic than the surrounding rocks, the relation to which, however, could not be ascertained. It may be an intrusion into the normal greenstones or a variation of the latter.

Other workings were inaccessible.

The general strike of the reef is about N10 deg. to 15 deg. E. The dip is easterly at about 80 deg., but at times it is almost vertical.

It is clear that a large amount of work has been done on this lease. The present owners have certainly worked hard, and given the lode a good trial. They sank the 130 feet shaft, and also did the driving at the 130 feet level, as well as putting in the drives at the 100 feet level, in which they met some old stopes. They state the first workings are about 15 years old.

From observation and from the information supplied, it appears that the gold is almost wholly confined to the quartz veins, that the latter are thin and tend to give out both in length and depth, and that there is therefore no strong reef, the lode merely consisting, as a rule, of thin veins ("stringers") in the kaolin. The latter is apparently highly decomposed greenstone, with the iron leached out by water circulating through the lode channel.

The water level is about 135 feet.

The returns to the end of April, 1914, show—"Lease 1001R, Westward Ho, 248.50 tons., 119.33 fine ozs. Lease (110R), now part 1001R, Ovens, 86.00 tons, 97.01 fine ozs."

QUEEN OF THE EARTH.—Most of the workings are in old lease 704R. As shown by the accompanying geological map of the chief mining area at Yerilla (Plate III.),

a number of shafts have been sunk, but the results do not seem commensurate with the work done. A very rich patch of gold was obtained here in the early days, and the various shafts have apparently been sunk to discover the continuation of the lode carrying this rich gold. Almost all the shafts are now inaccessible, so that what information has been obtained has been gleaned from little more than a surface inspection.

The country consists of schists, which are much decomposed at the surface, but they appear to be derived from a greenstone, as some massive forms of that rock are near at hand, and some gradations can be traced. The rocks strike a few degrees west of north, and dip to the east at a high angle.

The quartz reefs associated with the schists are generally parallel in strike and dip to the latter. The exposures of the reefs are, however, short and shallow, and those seen do not form a continuous reef but separate lines. They also vary much in thickness from a foot or less to one that was about nine feet thick. The latter, however, is quite exceptional, and consists of one main reef about two feet wide with the balance as stringy quartz and country. The average would probably not reach two feet.

The bottom of the quartz from which the rich patch was alleged to have been taken was pointed out underground to the writer, at a depth of about 20 feet from the surface. Here the quartz seemed to be lying almost flat, the under surface resting on decomposed schists, which are known as the "lode," in consequence, no doubt, of these schists having carried some gold. All that could be seen of the quartz mentioned was an exposed thickness of 18 inches and a length and breadth of six and four feet respectively. The writer was informed that much of this quartz had, of course, been removed, but that originally the block was about eight feet thick, and 12 feet long from north to south, but probably less wide. The schists here were apparently lying at a high angle to the west, but this is not certain.

The schist "lode" referred to is that which has been worked to a shallow depth at the surface, but the workings are now covered up. If this schist body, which was stated to be perhaps 20 feet wide, carried payable gold, it would be a lode-formation.

To the south-east there is a line of shafts, but the quartz here was apparently only a very thin vein, and is, no doubt, that referred to by Mr. Montgomery as to six to eight inches wide, parallel to and east of the Queen of the Earth workings and known as the King of the South (704R).

MT. CATHERINE.—No work was being done at this huge quartz "blow." The workings in connection with it have been briefly described by Mr. Montgomery in his 1905 report already mentioned. He points out that there was a battery at the mine, but that a good deal of

the quartz broken had evidently been too poor to crush, and was lying at the surface. He states that several shafts had been sunk, one being a large main shaft, the dump of which showed that very hard massive greenstone must have been encountered in it; and that the principal work done appeared to have been a large open-cut on the outcrop. There is little to add to Mr. Montgomery's account, as no work was being done at the time of the writer's examination, nor had anything been done apparently for some considerable time. The battery had been removed.

This quartz "blow" rises as a low conical hill, about 30 or 40 feet above the flats at its base. Judging by its outcrop, it is evidently a huge lens, which rapidly thins both to the north and to the south. In its thickest part it is probably over 30 feet thick, although a band of schist, six feet thick in places, runs through it in some parts. Its strike is about north and south, with a dip at a high angle (nearly vertical in places) to the east. There are evidently bands in the reef that are quite barren, and others that carry some gold, as some parts are practically untouched, while in others a moderate amount of work has taken place. Thus as seen from the top of the reef, one band about two feet thick has been worked from the surface to a depth of about 60 feet, whilst another band, about eight feet thick, has been worked from the large open-cut from the north for a depth of about 50 feet. But even these bands have evidently contained much quartz too poor to crush, judging by the large quantity still broken at the surface. No pronounced difference is observable in the quartz of the supposed auriferous and non-auriferous bands.

In addition to the north open-cut, a smaller one exists at the southern end, and several deep shafts have been sunk as noted by Mr. Montgomery.

On the top of the hill the country abutting the reef is a decomposed schist (evidently derived from the massive greenstones). The strike of its foliation planes is about N20 deg. to 40 deg. W. Thus this reef cuts across these planes. From the dump of one of the shafts, a hard fine-grained, massive greenstone may be obtained, which is very similar in general appearance to that of the Catherine Range. It may be regarded as belonging to the same rock mass as the latter.

The water level, judging by the eye, the depth of the surface of the water in one of the shafts, appeared to be about 70 feet below

OTHER WORKINGS.—These call for no special mention, such as are of interest having been described by Mr. Montgomery. Amongst these the "Tin Dog" reef, which is evidently that contained in lease 913E, occurs about two miles to the north of Mt. Catherine. Some work has been done on this reef, but nothing is going on now. The same remarks apply to the "Daisy" reef which occurs in lease 4152,

about three-quarters of a mile north of Mt. Catherine. It forms a bold outcrop or small "blow" of quartz, striking about N. 45 deg. W., and dipping at a high angle to the east. A fair amount of work has also been done along the belt running north-north-west from the main area at Yerilla (the latter of which comprises the Yerilla King and Viola reefs).

GOLD YIELD.

The following figures have been supplied by the Mines Department. They show the returns of the then working mines to the 30th of April last, and the total production from the Yerilla Centre to the 31st December, 1913. In addition to these returns, the figures representing the yield from the Yerilla King mine for May, June, and July have been kindly furnished by the owners, and as this mine has produced almost all the gold recently won in the district, there will not be much to add when the figures for the whole district are brought up to date.

Return showing Production to 30th April, 1914, from Mines working at that date.

Number of Lease.	Name.	Dollied and Specimens.	Ore treated.	Gold therefrom.	Average per ton.
		fine ozs.	Tons (2,240lbs.).	fine ozs.	fine ozs.
850R ..	Central East (see also Viola leases)	..	244·00	166·12	0·68
752R, 850R	Viola leases (see also Viola 693R)	9·64	2,011·00	1,896·96	*0·94
(693R)-752R	Viola	2·22	..	..	..
1001R ..	Westward Ho ..	..	248·50	119·33	0·48
(110R) now part 1001R	Ovens	..	86·00	97·01	1·13
851R ..	Yerilla King ..	..	4,925·50	3,656·03	0·74

* Excluding dollied and specimens.

The following are the figures showing the total production of gold from Yerilla Centre to 31st December, 1913:—

Alluvial.	Dollied and Specimens.	Ore treated.	Gold therefrom.	Average rate per ton.
fine ozs. 19·30	fine ozs. 3,105·39	tons (2,240lbs.). 14,965·46	fine ozs. 11,820·20	fine ozs. *0·79

* Excluding dollied and specimens.

The additional returns of the Yerilla King mine, which have been furnished by the owners, are as follow:—

		Tons.		Fine ozs.
1914—May	..	442.25	..	331.27
June	..	232.00	..	180.62
July	..	162.00	..	143.26
Totals	..	836.25	..	655.15

This makes a total yield from the Yerilla King mine to the end of July, 1914, of 4,311.18 fine ozs. from 5,761.75 tons, an average per ton of 0.75 fine ozs.

From the above figures, it is difficult to arrive at the yield from each reef. For instance, the return for the Viola leases, 2,011 tons for 1,896.96 fine ozs. includes leases 752R (= 693R) and 850R. There are at least three distinct reefs here no doubt included, one perhaps in 850R, that part of the east and west Viola reef in lease 752R, and the southern extension of the Yerilla King reef in the same lease. Then the returns from that part of the east and west Viola reef in lease 684R are not included. The returns when forwarded to the Mines Department would probably not distinguish the different reefs, and so they can only be recorded for the various leases.

The total production to the end of 1913 shows an average return of 0.79 fine ozs. without including the gold obtained from dollying and specimens, which (3,105.39 fine ozs.) represents more than one-fourth of the balance from crushing. This is a very fair average return. Including the dollied and specimens in the yield, gives an average of practically an ounce (fine) per ton.

WATER AND MINING TIMBER.

A good supply of water can be obtained at depths from about 70 to 100 feet, and this water, it is understood, can be used for general battery purposes. The water is also good stock water and fairly numerous wells have been sunk in the district for this purpose with satisfactory results.

As regards mining timber, mulga is almost the only kind available, and this has been largely cut out near the township. A fair supply, however, probably still exists a few miles out.

FUTURE PROSPECTS OF THE FIELD.

These depend upon two conditions, new payable reefs, and the payable character of those at greater depths than at present worked.

With regard to new reefs, some of course will no doubt be found. The actual history of Yerilla is not known to the writer, but Mr. Montgomery, writing in 1905, pointed out that the east and

west Viola reef was then a new discovery, and this reef has yielded a considerable quantity of gold. At that time, the Yerilla King reef had not been discovered, and probably would never have been found if the deep lead had not been located, as the latter covers up the former. The discovery of these two important reefs so comparatively late, therefore, gives reasonable hope that further ones are awaiting the prospector; but, of course, as each new find is made, the chance of new payable reefs grows less. Thus in a general way there is a prospect of new reefs but it is difficult to indicate specific areas where search might be made with some chance of success. The subject, however, will now be discussed.

The most important group of reefs yet found is that associated with the greenstones where the granite has intruded the former just to the west of Yerilla. These reefs comprise the Yerilla King, Viola, Melba, and Queen of the Earth. They occur, as already pointed out, in either granite or greenstone, but close to the junction of these rocks, and therefore such occurrence may be more than a coincidence, that is, there may be some significance in the best reefs being associated with the two rocks mentioned. Hence other similar areas may be worth examination. Two other small areas of granite have been located by the writer about two and a half and three and a half miles respectively south-east from Yerilla on the new Edjudina road. It must, however, be remembered that the granite associated with the known payable reefs is in the main auriferous belt of the district, and that gold is found along the whole belt more or less. The other granite areas referred to above are not, so far as known, in any defined belt, and hence notwithstanding the juxtaposition of greenstone, the conditions may not be favourable for the formation of auriferous reefs. Still junctions of granite and greenstone are, in Western Australia, good prospecting areas. Their possible value, therefore, in the Yerilla district should be borne in mind, and the reefs that do occur associated with the more northerly of the two small new granitic areas should be prospected. Search should also be made for further outcrops of granite in the greenstones, which no doubt exist, as all the small granite areas have probably not been discovered in the few rapid traverses made by the writer.

Numerous reefs occur in the auriferous belt running north-north-west from Yerilla, but these on the whole unfortunately do not appear to have been very payable. Still one new good reef would be of much value to the district. The reefs in the belt mentioned, together with the associated bedrock, practically reach the surface, there being scarcely any detritus. Thus there is little hope of new reefs along the known lines. This belt, however, forms part of a moderately wide and long flat, which has several north-south lines of drainage across it between zones of country showing reefs. These drainage lines possess as a rule no distinct channels, they

being merely broad flat surfaces (very slightly lower than the adjacent country) covered with a layer (probably thin) of red clay. In view of the distribution of the known reefs, it seems quite feasible that some reefs may underlie these channels. A few east and west costeens—if the detrital ground were not found too deep—across these channels might result in the discovery of some new reefs, perhaps of a payable nature.

It is a rather curious fact that when one gets away from the salt bush flats, which in the Yerilla district generally carry some quartz reefs, and reaches the slightly higher mulga-covered areas, few reefs are seen, and even, generally speaking, little quartz detritus. The disposition of the present known reefs suggests that this restriction to the lower country is not due to the actual distribution of the reefs, but rather that the latter occur over wider areas than are at present known, their absence of outcrop at the surface being due to concealment by a cover (perhaps only thin) of ferruginous cement. Hence costeeing across some of these areas is very desirable, but unless there be some key to guide such work, it would be mere "blind stabbing," which prospectors cannot be expected to undertake. The natural conditions of the country, and the scanty geological knowledge available over wide areas unfortunately do not at present supply such a key, with the possible exception of two small areas, viz.:—one (the more likely of the two) in size about one and a half miles square, south of Yerilla, west of the Bardoc road, and between the Westward Ho group of leases and those farther north, which form the beginning of the main auriferous belt; the other, west of the main (western) road to Pindinnie, commencing about three miles north of Yerilla, and extending northward for a little over a mile. This area lies in the line of the main auriferous belt, and forms a gap in the northern group of leases in such belt. As far as could be observed, there is little cement here, so that costeeing would not be difficult work.

There are various localities in the Yerilla district where quartz reefs outcrop fairly freely. These have no doubt all been prospected, and found to be unpayable, as they have been scarcely touched; but no harm will be done by mentioning some of these localities, as it is possible that a re-examination, in the light of present low costs, might result in some payable proposition being obtained. Three of these localities are: (a) A small belt running for a few miles north-north-east from Yerilla and traversed by the eastern track to Pindinnie; (b) a very small area containing reefs and "blows" within a mile north-west of Mt. Catherine, and within a mile west of the old Edjudina road; (c) the wide flat studded with numerous reefs, such flat commencing about three miles to the east of Yerilla, extending eastwards towards Lake Raeside, and northwards and southwards for some miles,

The high ridges of fine-grained and coarse-grained massive greenstones appear to be non-auriferous belts of country, but they are not of very great extent. Most of the prominent ones have been indicated on the accompanying geological sketch map (Plate V.).

With regard to the second aspect of the matter, that of payable gold at reasonable depths, not very much can be said. The Yerilla King mine has only penetrated the reef a little below 200 feet, and so far as known to the writer, these are the deepest workings on the field. There is, therefore, little direct evidence as to values or not at depth. The returns from the Yerilla King have, taking them altogether, been very fair as mines run nowadays, although of course there may have been richer and poorer zones, and the values in the lower portions may not have been so good as higher up. Although the reef at times rather suddenly thins, and even gives place to actual blanks, as well as possessing the undesirable rolls already described, still the ore-channel is usually well-defined, and gives the impression of being a moderately strong fissure, with a prospect of the reef living to a fair depth. Many of the other reefs of the district appear to lie between the planes of foliation of the schists and hence the ore-channels are probably not so well-defined both in length and depth. As to values there is no definite evidence for or against surface enrichment, although the rich patch found at the Queen of the Earth was no doubt due to such. So little is known of the occurrence of the gold, and the workings are so shallow, that discussion at the present stage is of no value. On, however, the nature of the Yerilla King reef, its containing fissure, and the yield of gold therefrom, alone, there appears to be a reasonable prospect of the reefs living to greater depths than at present known (with, of course, blanks), and of payable values, if worked with great economy and care. It must, however, be remembered that the reefs as a whole are of the "patchy" order, as regards continuity in length and depth, and have not been of a high grade. Under these circumstances, it cannot be expected that Yerilla will be a place for companies to any extent. It is essentially a locality for prospectors to the water level; and possibly, below the latter, for syndicates or small companies, with sufficient capital to cope with the increasing hardness of the rocks and with the water; to allow for dead work through the blanks; and to keep developmental work well ahead. Without a clear recognition of the necessity of these conditions, there is little hope for any permanent mining at Yerilla, even at moderate depths.

Another point is that there is every chance of various reefs meeting one another, as they dip both to the east and to the west, and their strikes are often irregular. Good values are sometimes found at such places, so that junctions should be sought for.

The possibility of lode-formations existing in association with the schistose rocks should also be borne in mind.

SUMMARY.

Yerilla is the centre of a small mining belt about 21 miles east-south-east of Kookynie.

Most of the country is flat, but occasional rather high ridges occur.

The general geology is simple. There are three chief series of rocks, basic, intermediate, and acid. The basic are the oldest and the other two may be approximately contemporaneous with one another.

The basic series consists of massive and schistose rocks, to all of which the general field name of "greenstones" has been given. The massive greenstones are divided into fine-grained, porphyritic and coarse-grained, the relations of which to the schistose rocks and to one another have not been definitely determined. The greenstones, especially the schistose group, carry most of the auriferous reefs of the field.

The intermediate series consists of a rock provisionally termed a syenite. It is intrusive into the greenstones, and is apparently non-auriferous.

The acid series consists of small intrusions into the greenstones of a granite, and of a number of acid dykes evidently genetically related to the granite. These dykes comprise aplites, quartz and felspar-porphyrries, probably granite porphyries, and felsite.

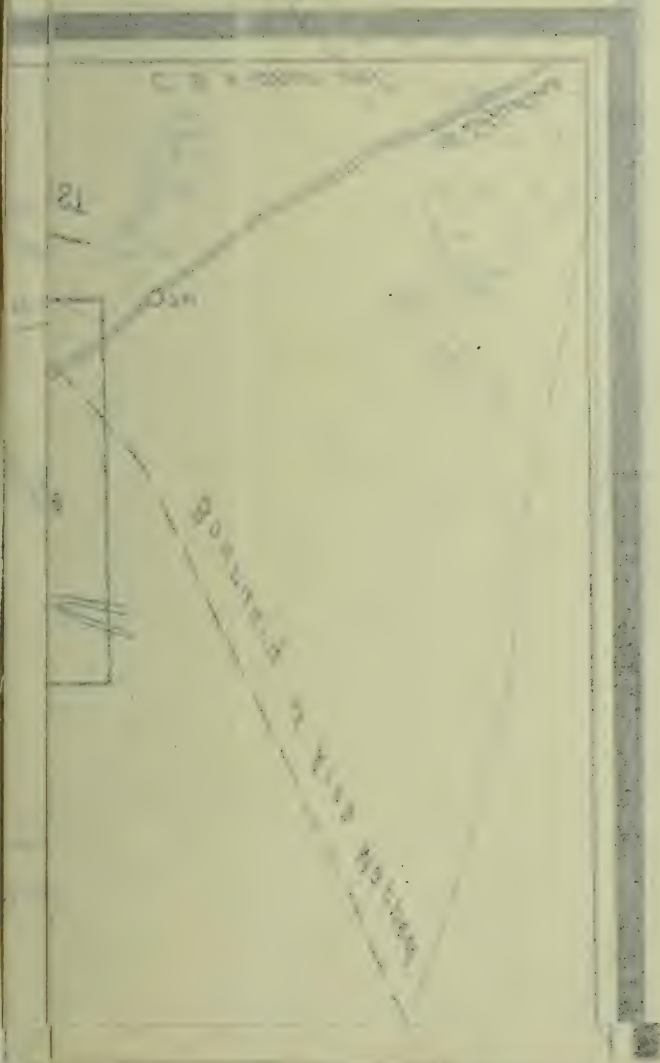
At the island at Lake Raeside, which lies to the east of Yerilla, but is somewhat outside the scope of this report, an interesting group of apparently ancient amygdaloidal basic lavas, and perhaps tuffs or volcanic agglomerates, occur, into which a highly basic rock penetrates as small dykes.

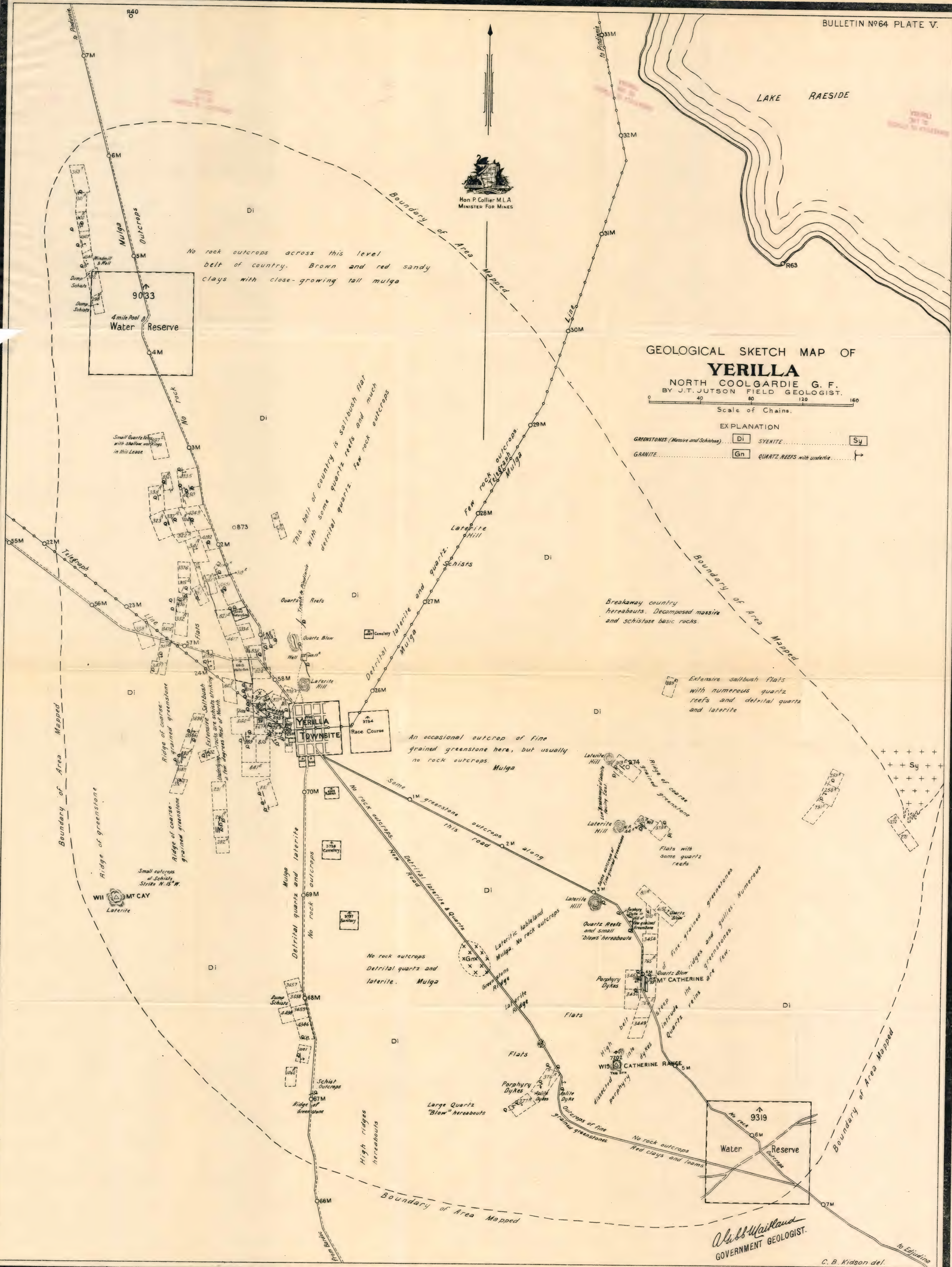
The lodes of the district are practically all quartz of varying thickness, but usually on the thin side, and with blanks. They vary in their strike and dip, but the strike of the lodes of the most defined belt is roughly north and south, with a prevailing dip to the east. As a rule, they are parallel in strike and dip to the planes of the schists, but some reefs cross these planes. There is only one well-defined auriferous belt at Yerilla, and that runs north-north-west past the town on its western side.

The most important reefs are just west of the town, and are associated with granite and greenstone. Whether this association is anything more than a mere coincidence has not been demonstrated, but similar areas, of which some exist at Yerilla, may be worthy of examination.

A brief account is given of the workings available for inspection at the time of examination including the Yerilla King mine.

A deep lead runs westward from the latter mine.





Shallow alluvial workings are few.

The future prospects of Yerilla are discussed, both as to new reefs and mining at depth.

In conclusion, the writer desires to acknowledge the courtesy extended to him, and the assistance he received from those associated with mining at Yerilla.

19th September, 1914.

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54.—CERTAIN MINING CENTRES AT THE SOUTH END OF THE YALGOO GOLDFIELD.

BY H. P. WOODWARD.

(With a Map, Plate VI., and three Figures.)

CONTENTS.

	PAGE.
Golden Eagle Group	46
Porcupine Group	46
Bonnie Venture Group	49
Crusoe Group	50

In pursuance of instructions, I journeyed to Yalgoo, at which point I was met by Mr. Deeble, the Inspector of Mines, who conveyed me in his motor-car first to Field's Find and from thence on to the various centres I had to examine.

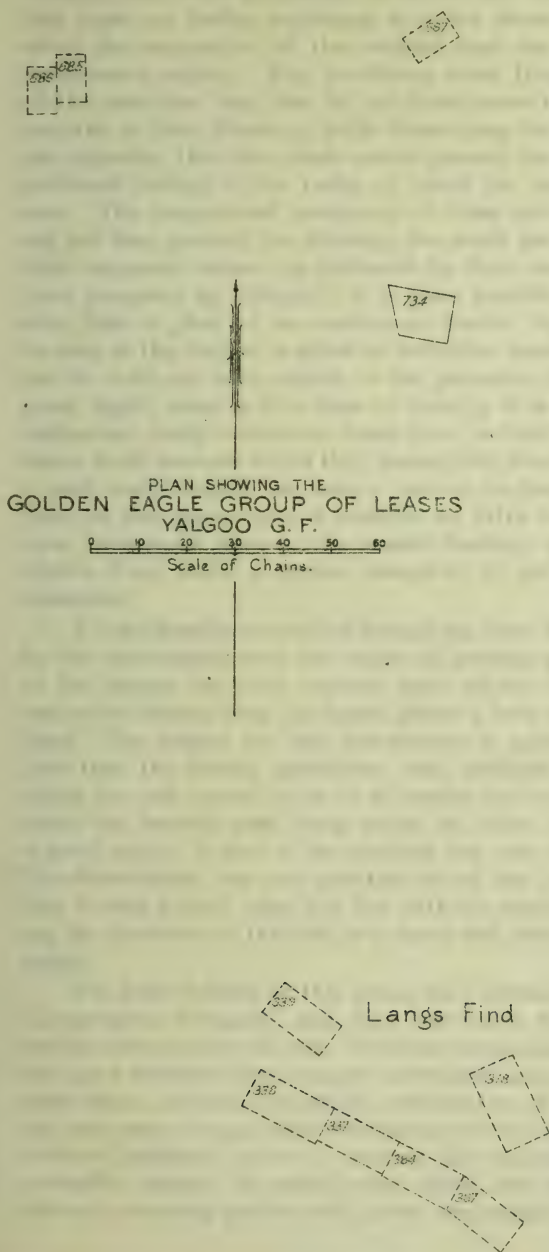
GOLDEN EAGLE GROUP. Fig. 1.

A few miles to the westward of Field's Find is a scattered group of leases and prospecting areas, but upon these very little work is being carried on at the present time. Two very rich leaders are being worked upon the edge of an old dry-blowing patch, and it is probable that these, with others, formed the source from which the alluvial gold was derived.

PORCUPINE GROUP. Fig. 2.

This group of leases is situated upon a low ridge of hills, about seven miles due west of Warriedar Trig. Station. Here gold-bearing lodes lie upon either side of one of those banded jaspery ironstone outcrops, which have commonly proved to be of such considerable economic importance upon the Murchison goldfield. This bar outcrops for a distance of about one mile having a main direction of north-west and south-east and is contained in greenstone schist rock, the precise nature of which cannot be determined from the weathered surface specimens. Although this bar has not so far proved to be auriferous, it is clearly a main shear line to which is due not only the formation of the parallel gold bearing veins, but it has also played an important part upon the deposition of gold in them by allowing the free circulation of the ground waters. These auriferous fissures differ in one point from the general characteristics of those of the Murchison in that they do not cross the shear zone, but maintain a parallel course to it. The bulk of the gangue

Fig 1



C.B.K.

in the auriferous lodes consists of chalcedony, jasper, semi-opal and hydrated oxides of iron with little quartz, while the presence of asbestos and allied magnesian minerals lead one to the conclusion that these ore bodies originated as minor shears along the line of which the composition of the crushed rock has been changed by metosomatic action. The auriferous veins lying upon either side of the main bar dip from it; *i.e.*, those upon the north-east side underlie in that direction, while those upon the south-west dip in the opposite, thus the whole series present the appearance of an antilinal folding of the rocks, of which the jasper bar forms the axis. The longitudinal continuity of these gold-bearing lodes has not yet been proved, for although the scrub has been cleared upon their supposed course (as indicated by float stones, which yielded good prospects by dollying), it is quite possible, and indeed probable, that in place of one continuous fissure, the ore will be found to exist in the form of a series of lenticular masses. No great hope can be held out with regard to the presence of gold values at a great depth, since in this class of country it is usually found that values are fairly consistent down to or a little below the ground water level, beneath which they perceptibly diminish. The want of a good water supply has been a serious hindrance to the development of this group since it entailed an extra cost of 25s. per ton upon cartage of stone to the nearest battery, which is situated at Field's Find, where a further charge of £1 per ton is incurred in treatment.

A considerable amount of boring has been done in this locality by the Government with the object of locating a water supply, but so far success has only crowned these efforts at one point, about two miles distant from the leases where a bore well pump has been fixed. The reason for this non-success is apparently due to the fact that the boring operations were confined to the valleys in which the rock proved to be of a massive and impervious character, while the fissured zone along which the lodes occur and in which a good supply is sure to be obtained has been left severely alone. The Government has now granted one of the lease holders a subsidy to sink a shaft upon this line with the combined object of testing the character of the lode at a depth and obtaining a good water supply.

The lease-holders of this group have formed themselves into a Co-operative Company, and have purchased the necessary plant for the treatment of the ore. This they have undertaken to erect as soon as a sufficient water supply is obtained and to crush at Government rates, provided the mill is subsidised by the State. So far as one can gauge from present developments these lodes do not promise to be of sufficient extent to warrant the expenditure of any considerable amount of capital upon them, but rather lend themselves to working parties who, given reasonable crushing facilities,

should be able to obtain handsome returns for their labour for a considerable time to come.

The Mug's Luck G.M.L. 708. King and Party.—This lease, which covers an area of 24 acres, is situated at the extreme north-west end of the group, but upon it there is no defined lode outcrop. 100 tons of stone was, however, raised from one bunch which yielded upon crushing gold to the value of £4 10s. 6d. per ton. A shaft has been sunk near the open-cut from which the crushing was taken to a depth of 30 feet, from the bottom of which a formation was crosscut for a distance of 20 feet in which the values were low.

The country is apparently a good deal disturbed at this point and will, therefore, need more prospecting in order to ascertain whether or not the main line of lodes extends into this lease.

The Aurum G.M.L. 711. Neville and Louter.—This lease of 13 acres immediately to the South-East of the last mentioned and upon it a well-defined ore body, having a north-westerly course, has been opened up by a shaft which cut it at a depth of 20ft. and followed it from this point upon the underlay to a total depth of 70ft. This lode dips in a south-westerly direction at an angle of 55 deg. and varies in the shaft from four to eight feet in width, while its value, arrived at by sampling, is said to range from 15 to 20 dwts.

The Warriedar G.M.L. 727. Hornhardt.—Upon this lease of 18 acres a shaft has been sunk to a depth of 70ft. upon a lode which strikes north-west and south-east, having a dip of 60 deg. to the south-west.

The country rock is weathered schist, in which the ore body averages about four feet in width, 38 tons of which, when crushed, yielded 20zs. 12dwts. of gold per ton of stone. A second crushing is now being treated, the whole being run of mine stone as raised from the development work.

The Porcupine G.M.L. 732. Olivers.—This 12-acre lease is situated and adjoins the last mentioned on the south-east side, and upon it a little prospecting has been carried on upon a series of small quartz leaders, one series of which follows a dolerite bar in a north-westerly direction, while another running north-east with a dip to the south-east shows traces of silicate of copper in places.

The Ironclad G.M.L. 699. King and party.—This lease, which covers an area of 24 acres, is situated at the extreme south-east end of the group and upon the eastern side of the "Jesper-bar." The strike of the lode is north-west, but its underlay is to the north-eastward. Two or three shafts have been sunk, the deepest of which is 50 feet from which the ferruginous lode matter has been cross cut, 15 tons of which yielded gold at the rate of 5 dwts. over the plates

Fig 2.

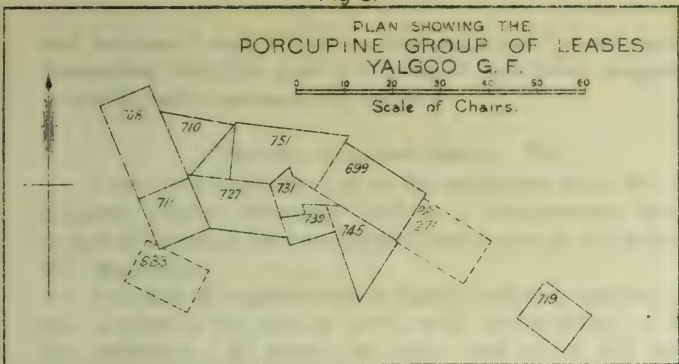


Fig 3.

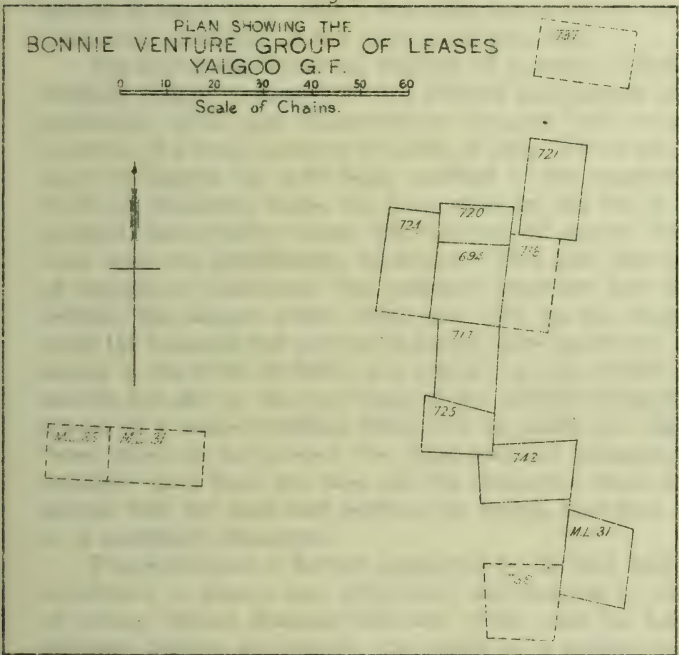
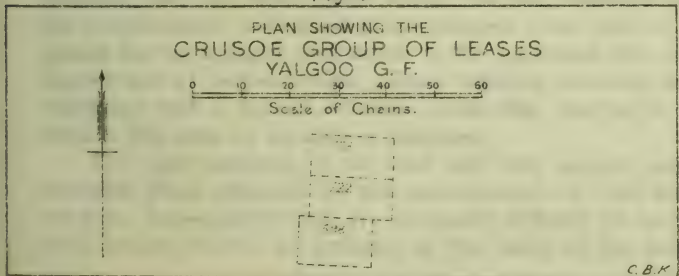
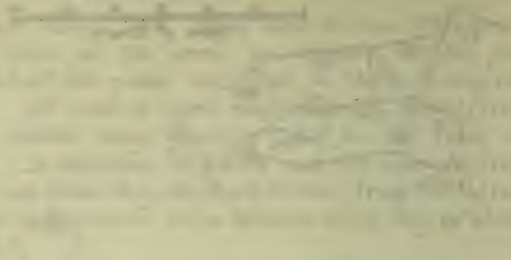


Fig 4.

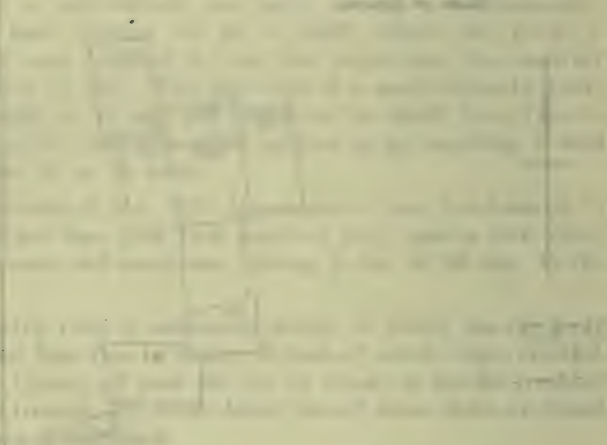


SECTION OF THE ...



SECTION OF THE ...

Scale of Feet



SECTION OF THE ...

Scale of Feet



and between 7 and 8 dwts. in the sands per ton of stone treated. Associated with this lode is a band of soft green magnesian rock, in which gold is occasionally visible.

BONNIE VENTURE GROUP. Fig. 3.

About two years ago one of the employees upon Mr. Connolly's Ninghan Station discovered gold in a conglomerate bed, situated in a belt of rough broken country, some five or six miles south of Mt. Singleton.

This bed of conglomerate is highly inclined, striking in a direction a little to the east of north with an underlay of 70 deg. to the westward. It forms the main axis of a hill which rises abruptly to an elevation of some 400 feet above the flat which surrounds it upon three sides. The Hill, owing to its steepness, is practically contained in the original 24-acre lease.

The geological formation consists of a series of beds of sedimentary origin, composed of fine grained argillaceous sandstones, sandstones, grits and conglomerates coloured red, owing to the presence of a small quantity of oxide of iron. There are no quartz reefs or fissures, the gold being confined to the conglomerate bed which is, therefore, called the lode, while in this bed it occurs in greatest concentration upon the footwall or eastern side, which rests upon the argillaceous sandstone. This lode mainly consists of ferruginous sandstone, with scattered quartzites and chalcedonic pebbles, the largest stones being met with on the footwall side, while the hanging wall portion is almost pure sandstone. The gold occurs in the form of flakes and grains not only in the sandstone matrix, but also in the very heart of the pebbles themselves. It is always in a semi-crystalline form such as scales and angular particles, which do not present the least trace of abrasion, as would certainly have been the case had its deposition been contemporaneous with the sand and pebbles; its origin, therefore, is clearly of a secondary character.

This conclusion is further supported by the fact that increased enrichment is always met with upon the footwall in the vicinity of certain oblique drainage channels, which cross the lode. These drainage fissures are clearly the result of a certain amount of shearing that has taken place along this line confined entirely to the conglomerate bed which they intersect from wall to wall, the planes having a slight inclination to the eastward, but only a few degrees out of perpendicular. These leaching channels are usually encrusted with a deposit of white china clay, varying in thickness from a thin skin to an inch in thickness.

The gold particles in the rock are very minute and closely resemble those obtained by the precipitation of that metal from solution, consequently they are extremely difficult to save by panning, which renders an estimate of the value of the lode by this

means impossible. It is stated that a series of average samples taken fairly across the formation yielded gold upon assay at the rate of one sample 4 dwts. and the other 5 dwts. per ton. A large series of much higher returns has been obtained, but these were obtained from picked stone. The so-called lode, so far as proved, varies from eight to 12 feet in thickness and has been traced for a length of about two miles, while another parallel bed of auriferous conglomerate has been opened up some 10 chains further to the eastward. It is quite impossible to express an opinion as to the value of this deposit without extensively bulk sampling, while the latter will prove a difficult operation, owing to the patchy manner in which the values occur.

In all some 16 acres have been pegged along a line of two miles, but so far development has been confined to the prospectors' lease, upon which Parker and Party have sunk their shafts, two of which have followed the lode down for 70 feet, and one 56 feet. This sinking from the top of this steep hill entailed a considerable amount of unnecessary labour, for this lode could have been much more satisfactorily and economically tested by driving a tunnel along the course of the lode from the end of the hill.

The value of the deposit upon the prospectors' lease could be cheaply and satisfactorily tested by driving tunnels from the base of the hill along the course, which would each have to be something like 500 feet in length; while by cross cutting the lode at intervals of not less than 50 feet, a very fair estimate of the value of the whole body would be obtained. If, subsequently, a level was taken over the top of the hill and the outcrop sampled by trenching, the cubic quantity and value of the stone could be estimated, when, if it proved to be of sufficient richness to warrant working, the whole of this huge mass (approximately 30,000 cubic yards), could be dropped by over-head stopes to the tunnel.

Owing to the character of the lode matter, it could be very cheaply mined and crushed, while its free leaching character would facilitate the extraction of the finely divided gold which could not be saved by any amalgamation process.

There is an abundant water supply in this district, while there is ample mining timber and fuel in the neighbourhood to last for a considerable time; therefore, should this huge body of ore prove to carry anything approaching the estimated 4 dwts., this should before long become an important mining centre.

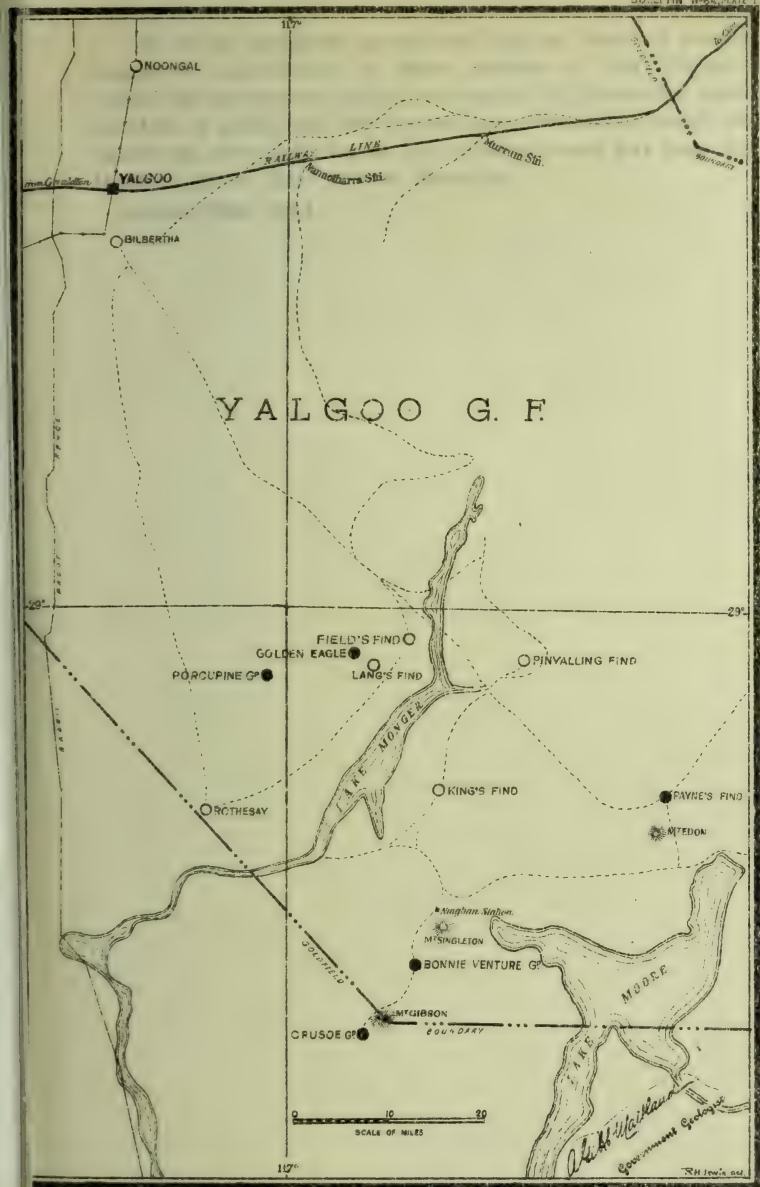
CRUSOE GROUP. Fig. 4.

A group of three leases is situated about 13 miles south of the Bonnie Venture and four miles south-west of Mt. Gibson.

Gold was originally discovered here some years ago by Tom Payne, but was abandoned by him owing to the large quantity of copper contained in the stone.

MAP SHOWING THE MINING CENTRES AT THE SOUTH OF YALGOO G. F.

SHEET 1111 N° 54, PART 1



H. J. Pether, Government Lithographer, Perth, W. A.



It is an extremely promising looking tract of country, very similar in appearance to those portions of the Yilgarn belt in which the greenstone schists are capped by travertine deposits. A number of small but rich leaders have been discovered, which are said to be very rich, but so far no actual work has been done upon them to prove their size or direction.

August 29th, 1914.

55.—CLASSIFICATION OF KALGOORLIE ROCKS.*

BY R. A. FARQUHARSON.

With the exception of rocks from the North End, Kalgoorlie, some specimens from the Commission on Miners' Diseases, and some collected by myself, I have not yet had an opportunity of studying the rocks of the Kalgoorlie Field as thoroughly as is required to draw up a classification that is to be regarded as final. Mr. Feldtmann and I, however, have been engaged in work on the area for some time past, and it is hoped that more light will be thrown on the rock relationships and origins at the conclusion of the work than has hitherto been thrown.

The first essential of any classification is that it has a uniform basis. In the proposed amended one, some divisions are based on the origin of the rocks, *e.g.* peridotite, pyroxenite, others on their present composition and structure, and others again merely on their present external appearance, *e.g.* aphanite. It must be admitted that, owing to the generally altered nature of the rocks, a uniform classification according to origin is at present impossible of attainment. Consequently it is evident that the basis of most value with an approach to uniformity is that on which the rocks are classified according to their present composition and constitution. This is the basis, therefore, that has, for the present, been adopted by the Geological Survey. In two cases that of the "Peridotite" and that of the "Rocks of gabbroid and doleritic Origin," it has been considered advisable, with a view of showing the relations existing between the various members, to group the latter under general divisions based on origin, but the minor divisions are still based on the mineral composition and the constitution of the rocks.

In making a full classification of the rocks, a difficulty arises as to the extent to which the application of "Kalgoorlie Rocks" may apply. If the area embraced may be held to include Hannan's Lake, then an additional type, Serpentine, must be introduced.

The classification, therefore, that investigations up to the present have enabled this office to draw up is as follows:—

1. Calc-schist.
2. Altered peridotite: (a) Fuchsite-carbonate rock, (b) Serpentine at Hannan's Lake.
3. Rocks of gabbroid and doleritic Origin:—
 - (a) Amphibolites.
 - (b) Talc-chlorite rocks.
 - (c) Altered quartz-dolerite.

* Reprinted from the Monthly Journal of the Chamber of Mines of Western Australia, Vol. 13, Pt. VII., 1914.

4. Bleached and carbonated rock.
5. Sericite-carbonate rock.
6. Felsitic quartz porphyry.
7. Slates.
8. Porphyrite.
9. Albite porphyrite.

There is no chronological order in the arrangement.

To compare this classification with the amended one from the Mining and Scientific Press:—

1. Nothing definite is at present known about the origin of the "Calc-Schists," and, since the name "Calc-schist" is now one with a distinct local connotation, and since it is to some extent expressive of the composition and structure of the rock, there appears no good reason to alter it until more work has discovered the origin of the rock.

2. No true Peridotites have so far been discovered among the Kalgoorlie rocks by officers of the Geological Survey. The "fuchsite-carbonate" rock which occurs in places may have been derived from such ultra-basics, but so far nothing definite can be stated in this connection. The black Serpentine at Hannan's Lake has in all probability been derived from a peridotite, but it is doubtful if it may be held to be embraced in the area under consideration. The Talc-chlorite rocks, however, may be much altered facies of a former peridotite, since talc is a frequent alteration product under certain conditions of olivine. It must be noted, however, that talc is also well-known as a derivative of both hornblende and pyroxene.

3. With regard to the pyroxenites, while some of the greenstones have been produced by alteration of these, so far as this Office is concerned their presence has not been definitely established in the Kalgoorlie Field, while that of amphibolites has been. It has appeared, therefore, to be much more judicious to substitute for the group Pyroxenite another more comprehensive division—Rocks of gabbroid and doleritic Origin—and to include in it, not only amphibolites but those talcose-chloritic rocks of which the exact origin is still somewhat doubtful. In this group, also, comes the altered—amphibolised and zoisitised—quartz-dolerite with micropegmatitic areas, such as occurs at Warden's Hill.

5. The term "aphanite," so far as discrimination of rocks either according to origin or according to mineral composition is concerned, is practically meaningless. The term is descriptive merely of the macroscopic structure, and signifies a type that is glassy, or of exceedingly fine grain. The non-chloritic rock to which this term has been applied, while undoubtedly fine-grained, can easily be made out to consist largely of sericite and a carbonate (with quartz and probably albite), and, though its origin is a matter of dispute, it will be much more intelligibly and satisfactorily classified as a non-chloritic sericite-carbonate rock, especially since the term "aphanite" can apply to a rock of almost any composition.

6. In the amended classification, the felsite is held to be synonymous with Maclaren's albite-porphyry. This is a mistake. The observations of Mr. Feldtmann and myself in the North End, Kalgoorlie, have established the presence there of an undoubted ablite-porphyrine (*see* Petrology of North End, Kalgoorlie, Bull. 51, p. 52, *et seq.*). Larcombe* notes amongst the rocks of the Golden Mile a felsite porphyry, generally, though not always, pink in colour. Though this rock has not been expressly noted by officers of the Survey,† a pink felsitic porphyry has been determined from the Binduli area.‡ There is little or no doubt, therefore, that both an albite porphyrite and a felsitic quartz porphyry occur in the area and both are quite distinct from one another. The "Felsite," then, of the amended classification is represented in the classification of the Geological Survey by Felsitic quartz porphyry and an additional division Albite-porphyry (No. 9) is introduced which has no counterpart in the amended table.

7 and 8. For want of a more accurate term "Slates" cannot well be altered, while Porphyrite signifying the "spotted" rock is sufficiently accurate for general purposes.

Amended Classification (Mining and Scientific Press).	Geological Survey.
1. Calc-schist	1. Calc-schist
2. Peridotite	2. Altered Peridotite— (a.) Fuchsite-carbonate rock (b.) Serpentine at Hannan's Lake
3. { Pyroxenite Quartz-dolerite	3. Rocks of gabbroid and doleritic origin— (a.) Amphibolites, etc. (b.) Talc-chlorite rocks (c.) Altered quartz-dolerite
4. Bleached dolerite	4. Bleached and carbonated rock
5. Aphanite	5. Sericite-Carbonate rock
6. Felsite	6. Felsitic quartz porphyry
7. "Slate"	7. "Slates"
8. Porphyrite	8. Porphyrite
9. —	9. Albite porphyrite

31st July, 1914.

* Geology of Kalgoorlie. Trans. Aust. Inst. Min., Eng., Vol. XIV, 1912, p. 71

† Since this was written an examination has been made of specimens in the Survey collection of Felspar Porphyry, collected some years ago by Mr. Gibb Maitland, and described in G.S., W.A., Bull. No. 6, pp. 72-74. These undoubtedly include a pink carbonated and a cream-coloured felsitic quartz-porphyry.—R.A.F.

‡ Petrographical Notes in G.S., W.A., Bull. 56.

56.—ON CONCENTRATION TESTS OF A TUNGSTEN-MOLYBDENUM ORE FROM CALLIE SOAK, POONA, MURCHISON GOLDFIELDS.

BY ALEX J. ROBERTSON, M.Sc.

CONTENTS.

	PAGE
Concentration Tests	55
Method of Assay	61

Concentration Tests.—A sample from the Murchison Field submitted under the Public Assay Regulations was found to consist of a mixture of Molybdenite (sulphide of molybdenum, MoS_2 , Scheelite (tungstate of calcium, CaWO_4), and a smaller amount of Wolfram (tungstate of iron, FeWO_4) in a gangue of Quartz, Mica, and Kaolin (clayey matter). This ore is too close-grained for hand picking, though other portions of the lode may be suitable for grading in this way. The assay value of the ore was:—

Molybdenite (MoS_2)	2.02 per cent.
Tungstic oxide (WO_3)	9.07 per cent.

The mineral composition was approximately:—

Molybdenite	2 per cent.
Scheelite	10 „
Wolfram	$1\frac{1}{2}$ „
Gangue	$86\frac{1}{2}$ „

It is desirable that concentrates of these minerals, when placed on the market should run, in the case of molybdenum ores, at least 90 per cent. of Molybdenite, and for tungsten ores at least 60 per cent. of Tungstic oxide (WO_3). Lower grade parcels would probably receive no attention or be subject to serious deductions. It will be seen therefore that the ore requires considerable concentration.

Since all the valuable minerals are considerably heavier than quartz* and the other gangue, water concentration first suggests itself. Molybdenite, however, has the property of floating on the surface skin of water, which prevents its concentration by gravity as long as it remains on the surface. And it is practically impos-

* Sp. gr. of Wolfram = 7.35, Scheelite = 6.00, Molybdenite = 4.75.
Quartz = 2.65.

sible to overcome, with any completeness, this surface tension effect between water and this mineral. An attempt was made to concentrate the Molybdenite in this way, but, as was to be expected, it failed completely. Further a concentration of the individual hardness of the component minerals suggests trouble, because two of the heaviest minerals, Scheelite and Molybdenite, are extremely fragile, particularly when in the granular condition in which they exist in this ore. We can therefore expect loss by sliming. The method finally decided upon was in outline, to (1) remove the Molybdenite by flotation, (2) to obtain the Scheelite and Wolfram from the residue by gravity concentration. Thus it is very evident that the ore is more difficult of treatment than a simple Molybdenite or Wolfram ore with quartz as gangue.

Two series of experiments were carried out, one on a portion crushed to pass an 80 mesh sieve, the other on a portion crushed to pass 30 mesh, the number of holes being reckoned per linear inch. Satisfactory results were only obtained from the latter as the following table shows:—

Size of Ore.	Kind of Concentrate.	Weight of Concentrate per cent. of ore.	Assay Value.	Recovery on original ore.
80 mesh	Molybdenum ..	1.71 %	37.8 % MoS_2	31.9 %
	Tungsten ..	12.9 %	36.3 % WO_3	51.7 %
30 mesh	Molybdenum, crude	6.01 %	20.8 % MoS_2	61.9 %
	„ refloated	1.01 % (A)	75.0 % „	37.5 %
	„ treated	0.87 % (B)	92.9 % „	39.8 %
	on 90 sieve			
	Tungsten ..	12.6 %	57.5 % WO_3	79.9 %

80 mesh sample.—A good deal of this was much finer than 80 mesh. 100 gramme sample was taken and the ore sprinkled on to the surface of water in small quantities at a time. The Molybdenite-bearing scum was decanted through a filter, the residue stirred briskly and the extra Molybdenite brought to the surface by this means was also filtered off. The total concentrates weighed 1.71 grammes and assayed as above. This is unprofitable on account of not only the low grade concentrate but also the poor extraction. No oil was used in these tests, and this may in part account for the poor extraction. At the same time the large amount of clayey slime present, reduces the Molybdenite value of the concentrates by simple adulteration. It also seems to give a poor extraction by encasing the Molybdenite particles with fine dust, thus fouling or clogging them and preventing them from floating freely. The residue after the removal of the Molybdenite was panned down in the usual way to obtain the tungsten values. There was again a

good deal of sliming, and much of the Scheelite was lost in this way. The weight of concentrates was 12.9 grammes and assayed as previously stated. Here, too, both the grade of concentrates and the recovery are unsatisfactory, a result largely if not wholly due to overfine grinding of the ore. However, the results obtained from the next tests on coarser crushed ore are much more hopeful.

30 mesh.—This material as with the 80 mesh portion, was also over-crushed, *i.e.*, in addition to all of it passing through a 30 mesh sieve, quite half of it would also pass a 60 mesh sieve. This lack of uniformity in the crushed product is a very undesirable feature, and there is no doubt that with coarser and more uniform crushing even better results than those actually obtained could have been obtained. Owing to the diversity in hardness of the ingredient minerals, more than ordinary care is required in crushing this ore. This extra care will be more than paid for in the greater effectiveness of the subsequent treatment and the ensuing higher grade extraction. The crushing plant should not be fed with excessive quantities of ore at a time, otherwise over-crushing will surely occur. And every endeavour should be made to obtain uniformity in size of ore particle—in this case between 30 and 40 mesh. Of course, some sliming is unavoidable but it is only a small fraction of that which would be produced from haphazard crushing, and the less slime formed the more successful will the concentrating operations be. This feature of the problem may seem to have been unduly stressed, but its importance might not have been sufficiently appreciated if it had been dismissed in a few lines.

As before, 100 grammes of ore were taken and the Molybdenite removed first. This time the effects of oil and acid were investigated in addition to simple flotation on water. The separation was carried out in three stages. First using water flotation alone, the ore was sprinkled on to the surface and the scum decanted off. Vigorous stirring and blowing of air through the pulp caused very little more sulphide to rise. Oil was then added in different proportions from 1 in 10,000 to 1 in 1,000, the whole being vigorously agitated in a closed vessel with each addition. The amount of scum formed each time was noted, and when the proportion of oil added had reached the latter figure, it was found to be sufficient. Further addition of oil did not extract any more Molybdenite. The total scums from the oil flotation were then set aside. Probably with a richer ore more oil would be required, the amount being determined by experiment. The oil used was the ordinary commercial Phellandrene obtained from the tree *Eucalyptus amygdalina*. An acid treatment was now combined with the oil. The ore residue was shaken vigorously with the oily water (1 in 1,000) and varying amounts of sulphuric acid were added in proportions from 1 in 10,000 to 1 in 1,000. The use of acid is not warranted because as will be seen from the table be-

* Hardness of Quartz = 7, Wolfram = $5\frac{1}{2}$, Scheelite = $4\frac{1}{2}$, Mica = $2\frac{1}{2}$,
Molybdenite = $1\frac{1}{2}$, Kaolin = 1.

low, the additional recovery of sulphide is so small. The acid did no harm, but was unnecessary so long as air was carried into the pulp by agitation or blowing. The weights of the various extracts were as follows:—

Treatment.			Weight of Concentrate.
Water alone	..	..	2.785 grammes
Water and oil	..	..	2.948 „
Water, oil, and acid	..	..	0.276 „
Total			6.009 „

Each extract contained a considerable amount of slimes in addition to Molybdenite; but as the aim was primarily to obtain a good recovery even at the risk of producing a lower grade concentrate, it was found impossible to avoid this. The assay result as already given was 20.8 per cent. of Molybdenite, equal to an extraction of 61.9 per cent. of the total Molybdenite in the ore. This recovery was rather disappointing but was the best obtainable. The concentrate also was too low grade for the market as it stood. About 79 per cent. of slimy gangue constituted the valueless portion. Two methods were therefore adopted with a view to improve it, (a) a second water-oil flotation with agitation, (b) a simple screening through a 90 mesh sieve rejecting the portion which passed through. The latter process gave better results. The recovery was slightly higher and the grade much better with sizing than with the flotation treatment, though in both cases the actual percentage recovery of the ore value was very low. Its simplicity makes the method (b) of increased value, and it will be noted that it is only about 6 per cent. of the ore crushed that would need screening. Since screening operations are troublesome the smaller the quantity of material that must be dealt with in this manner the better. The results of these two tests are also included in the table on page 2. For every ton of ore treated by flotation and followed by sizing of concentrate, about 18lbs. of high-grade Molybdenite concentrate would be produced, and this at, say, £450 per ton would be equivalent to about £4 gross return per ton of ore mined, Molybdenite to the value of about £6 per ton being left in the tailings.

It might be thought possible to get a high grade Molybdenite concentrate by a single treatment, but this is not so. Slime is always formed in greater or lesser amount and this will always collect with the Molybdenite either from suspension in the water or by actual floating on the surface film.

The effect of slimes on the grade of concentrate was brought home more forcibly by the following experiments. A sample of crushed ore (30 mesh) was sized into three portions and the Molyb-

denite in each lot was floated off on water alone and collected. The results which are almost self-explanatory are:—

—	Sized Portion.	Recovery.	Grade of Concentrate.	Improvement by re-treatment.
30-90 mesh	62·3 grammes	Very good	abt. 70 % MoS ₂	Possible (no slime)
90-150 „	10·7 „	Good	abt. 40 % „	„
150 and finer	26·5 „	„	abt. 5 % „	Impossible * (slime)
Loss dust ..	0·5 „	80-90 %	..	..
Ore taken ..	100·0 „			

* Not worth first treatment, should go straight to dump.

NOTE.—Both “recovery” and “grade of concentrate” estimated by eye only, no actual assay made.

Perusal of this table shows one very obvious advantage of preliminary sizing. It entails better recoveries in each case than obtained by direct treatment of the unsized ore. It is also to be noted that the grade of concentrate falls off as the fineness increases. Since it would not pay to size the ore in a treatment plant in this way, the aim should be, as has already been emphasised, to crush the ore to a uniform size—30 mesh found most suitable—avoiding sliming by careful crushing.

For the recovery of the Tungsten values, the remainder of the 30 mesh sample left after removal of the Molybdenite was concentrated by panning. A concentrate free from slime and weighing 12·6 grammes was easily obtained. As both assay value and percentage recovery indicate, it can be taken as quite satisfactory. Again, a great part of the loss is attributable to over-crushing. Every ton of ore treated would yield about 270lbs. of tungsten concentrate running about 60 per cent. of tungstic oxide (WO₃). This concentrate at, say, £1 10s. per unit, *i.e.*, each per cent. of the oxide, is worth £90 per ton. The return for Tungsten on the ore under the conditions of the experiments would be £10 16s. per ton mined, leaving Tungsten to the value of £2 14s. in the tailings.

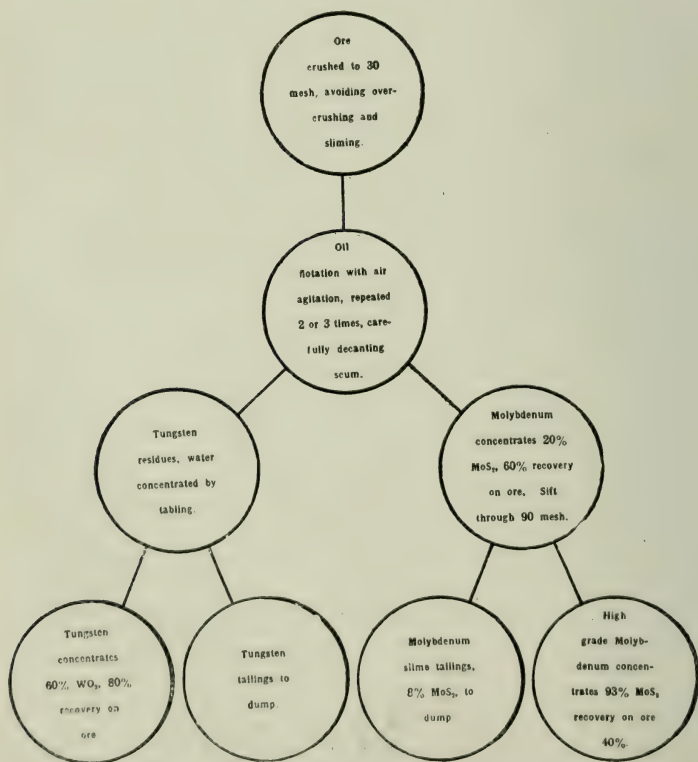
The complete distribution of values indicated by the experiments on ore crushed to pass a 30 mesh sieve are therefore:—

Per ton of ore.	Molybdenum.	Tungsten.	Total.
	£ s. d.	£ s. d.	£ s. d.
In ore	10 0 0	13 10 0	23 10 0
In concentrates	4 0 0	10 16 0	14 16 0
In tailings	6 0 0	2 14 0	8 14 0

These results have been obtained by flotation of the Molybdenite with oil at atmospheric pressure, and simple gravity concentration of the Scheelite and Wolfram. The recovery of the latter presents no difficulties and should be carried out successfully on ordinary concentration tables provided that care be taken to avoid grinding the more fragile Scheelite into slimes.

Two other methods are in use for the concentration of Molybdenum ores, viz.:—(a) Flotation *without* oil at atmospheric pressure; (b) Flotation *with* oil under a partial vacuum (Elmore process). The former is reported to have proved quite successful in Queensland, whilst the latter is claimed by the owners of the patents to have yielded extractions of 90 per cent. on Norwegian ores.

The complete scheme of operations for the treatment of this ore with a view to recovering as much as possible of its commercially valuable contents is most simply represented in a flow-sheet diagram thus:—



Since the ore, however, is worth only £4 per ton for its Molybdenum values, as against £11 per ton for its Tungsten, it would probably not be worth while making an elaborate treatment for the recovery of the Molybdenite. The more economic process would be to treat it directly for its tungsten contents, and catch any chance Molybdenite that comes off without making any extensive provision for doing so. Should, however, future better regulated and non-sliming crushings than those obtained in the above experiments result in a much improved recovery of Molybdenite, the installation of a special flotation plant would almost certainly prove itself a payable proposition.

Method of Assay.—The simplest procedure with this ore is briefly as follows:—(1) roast at a low temperature, (2) make an ammoniacal extract of the roast and estimate the molybdenum in it by direct evaporation and ignition, (3) estimate the tungsten in the residue first by removing the iron and lime with aqua regia, then dissolving out the tungstic acid with ammonia and recovering it from solution in the same way as the molybdenum. Half a gramme for high grade ores or concentrates, or two or more grammes for low grade ores are suitable quantities to take for assay.

The applicability of the method depends on the fact that roasting quantitatively converts MoS_2 (Molybdenite) into MoO_3 which is completely soluble in ammonia, while Wolfram (FeWO_4) and Scheelite (CaWO_4) are unaffected by roasting and subsequent digestion with ammonia. A simple separation of two very closely related elements is thus easily effected. Treatment with aqua regia completely decomposes both Wolfram and Scheelite, the tungsten being precipitated as yellow tungstic acid while the iron and lime remain in solution. Tungstic acid dissolves readily in warm ammonia and is thus easily separated from the insoluble siliceous gangue.

The roasting is best carried out in a platinum dish placed upon an inverted scorifier just inside the mouth of the muffle; in this way the oxidation proceeds at a uniform temperature throughout as the heat supplied is almost wholly radiant. The temperature must not be too high or MoO_3 is volatilised. The degree of heat is just below a dull red, *i.e.*, 600 deg.—650 deg. C. A crystal of potassium iodide serves as a convenient indicator as it melts at a few degrees below 650deg. C. Even at this temperature small quantities of MoO_3 seem to be volatilised if the heating is prolonged. In order to avoid this and yet get complete oxidation of the sulphide, it was found better to roast in a number of short stages rather than in one long one of the same total time, making between each roast an extraction of the molybdic oxide formed, with warm ammonia solution. Three roasts of 10—15 minutes each are generally sufficient but in all cases the final residue should be examined with a lens to see that it is free from undecomposed molybdenite. The roast is

warmed each time for about 5—10 minutes with strong ammonia, stirring now and again to facilitate solution. It is filtered by decantation and washed with dilute ammonia (about 1E). Two or three washes are sufficient for each extraction except the last, when about six should remove all the molybdenum. Each filtration is made into the same beaker, the filter paper and its adhering residue being returned each time to the platinum dish and ignited during the next roast. The bulk of the solution should be kept down; a 7 cm. filter paper will be found quite large enough. The combined filtrates of ammoniacal ammonium molybdate are now evaporated down to complete dryness on the water-bath, in order to render insoluble any silica which may have gone into solution. When cool about 5 c.c. of strong ammonia solution are added to the dry mass and after a few minutes warming it is filtered through a 5 cm. paper into a weighed porcelain crucible of about 20 c.c. capacity which is then placed on the sand-bath. The filtration is necessary to remove the small amount of white fluffy material which generally appears at this stage; this material does not contain molybdenum. The filtrate is usually blue in colour from the presence of lower molybdic oxides. The final washing with dilute ammonia should be performed about nine times according to the percentage of molybdenum present; the washings being added to the porcelain crucible as evaporation permits. The evaporation is carried to complete dryness, when the crucible is removed and gently ignited over a bunsen while the precipitate changes in colour from blue-green to black and finally to pale yellow. It is immediately removed, cooled and weighed as MoO_3 . If there be any darkish patches which do not readily change by heating to the yellow oxide, addition of a drop of nitric acid with evaporation and re-ignition will remedy matters. Here again as with the roasting, prolonged heating over the bunsen must be avoided; the ignition must be very carefully performed. This final ignition and the initial roast are undoubtedly the most prolific sources of error because overheating causes volatilisation of MoO_3 and consequent low results. At the same time, with careful attention to these two points, results of sufficient accuracy for technical requirements are readily obtainable.

The subsequent treatment of the ore for its tungsten contents calls for few remarks. After the extraction of the molybdenum, the residue filter paper and all is dropped into a beaker and warmed with 10 c.c. of *aqua regia* for about 15 minutes. (If the material was finely ground in the first instance complete decomposition is effected in this time; if not a second treatment is necessary, but it should not be made until the main precipitate of tungstic acid has been removed with ammonia.) After digestion with *aqua regia*, the solution is diluted to quite 10 times its volume with water and let stand on the water or sand bath for 30 minutes to one hour. This precipitates the small amount of tungstic acid sometimes held in solution by the strong acid. The assay is then filtered by decanta-

tion and washed free from iron with dilute hydrochloric acid (1 per cent.) solution. Dissolve the residue in the beaker with a few c.c. of warm ammonia, standing it for about 15 minutes on the water bath. Filter through the same paper and wash quite nine times with dilute (1E) ammonia. Evaporate the filtrate to complete dryness to throw any dissolved silica, etc., out of solution and when cool add 5 c.c. ammonia and warm till all the ammonium tungstate is in solution (10 minutes or so). Now filter into a 20 c.c. weighed porcelain crucible and evaporate to dryness on the sand bath, adding washings as bulk of the solution decreases. When quite dry, remove and ignite over a full bunsen till the colour of the contents is a deep yellow, cool and weigh as WO_3 . There is no danger of volatilising the tungstic oxide even with the blast, though use of the latter is not necessary.

Instead of extracting tungstic or molybdic oxides with ammonia alone, some authorities recommend the addition of ammonium nitrate to prevent the ammonia from taking silica, etc., into solution. This, however, is not always perfectly effective (evaporation to dryness is safest). It also has the disadvantage of causing the solution to creep in a most annoying way during the evaporation in the porcelain crucible, so much so that unless incessant watchfulness is exercised the salts may extend right over the top and possibly vitiate the results. If ammonium chloride is used the creeping is reduced but unfortunately this salt cannot be used in the case of molybdenum because it causes a partial volatilisation during ignition. The amount of siliceous matter that goes into solution at any time is very small, even if ammonia alone be used, and this is easily removed again by taking the solution to thorough dryness.

2nd April, 1914.

57.—ON CHLORITOID AND ITS CONGENERS.

With special reference to the Chloritoid of Yampi Sound.

By EDWARD S. SIMPSON, B.E., B.Sc., F.C.S.

With six Figures (Plates VII. and VIII., and Figure 5).

Chloritoid and its congeners form a sub-group of the Clintonite or Brittle Mica Group, which to some extent bridge the gap between the true Micas and the Chlorites. The natural classification of this sub-group has long been a matter of controversy, which is even now not finally settled, and as the examination of a mineral belonging to it and coming from the West Kimberley District of this State appeared to throw some light on the subject, the question has been gone into somewhat thoroughly.

Nine minerals have been described at various times as belonging to this sub-group.* The complete list, with type locality, author and date is:—

- (1.) Phyllite, Sterling, Mass., U.S.A. Thomson, 1828.
- (2.) Chloritoid (Chlorite-spar), Kossobrod, Russia. Fiedler, 1832.
- (3.) Masonite, Natic, R. I., U.S.A. C. T. Jackson, 1840.
- (4.) Ottrelite, Ottrez, Belgium Des Cloiseaux and Damour, 1842.
- (5.) Sismondine, St. Marcel, Italy. Delesse, 1843.
- (6.) Newportite, Newport, R.I., U.S.A. Totten, 1857.
- (7.) Struverite, St. Marcel, Italy. Brezina, 1876.
- (8.) Venasquite, Venasque, France. Damour, 1879.
- (9.) Salmite, Vielsalm, Belgium. E. Prost, 1883.

Although all described originally as specific minerals, many of these had a very short life as such, being soon recognised, on comparison with earlier described minerals, as specifically identical with them. Thus Struverite was found to be identical with Sis-

*Dana, System of Mineralogy, VI., 640-2, and Hintze, Handbuch der Mineralogie, II., 669-71.

mondine from the same locality, and both in turn to be only magnesian varieties of Chloritoid. Newportite was shown to be identical with Masonite, and both with Chloritoid. Analysis proved that there was no difference between Phyllite and Ottrelite, and that Salmite (and Masonite in part) was only a manganiferous variety of Chloritoid. Venasquite and Ottrelite appeared to be closely related.

Taking into account these relationships and rejecting the proved misnomers, we are left with the following series:—

Species.	Sub-species.	Formula.
Venasquite or Ottrelite	Normal, <i>Venasquite</i> ..	$\text{H}_2\text{O}.\text{FeO}.\text{Al}_2\text{O}_3.3\text{SiO}_2$
	Manganiferous, <i>Ottrelite</i> ..	$\text{H}_2\text{O}.\text{(Fe,Mn)O}.\text{Al}_2\text{O}_3.3\text{SiO}_2$
Chloritoid ..	Normal, <i>Chloritoid</i> ..	$\text{H}_2\text{O}.\text{FeO}.\text{Al}_2\text{O}_3.\text{SiO}_2$
	Manganiferous, <i>Salmite</i> ..	$\text{H}_2\text{O}.\text{(Fe,Mn)O}.\text{Al}_2\text{O}_3.\text{SiO}_2$
	Magnesian, <i>Sismondine</i> ..	$\text{H}_2\text{O}.\text{(Fe,Mg)O}.\text{Al}_2\text{O}_3.\text{SiO}_2$

In this provisional classification we are reduced to two single species, viz., a monosilicate Chloritoid, and an apparent trisilicate, forming a species usually referred to as Ottrelite, though the normal subspecies is Venasquite and not Ottrelite proper. The former name would appear to be more logical to use, but Ottrelite has priority by many years, and has been widely applied. However, as will appear later, since both names should apparently yield to Chloritoid,† the question of the relative use of Venasquite or Ottrelite need not be pressed further.

The basis of this specific grouping is the apparent marked difference in the ratios of silica to the bases, which latter amongst themselves have the same ratio in both Chloritoid and Ottrelite. Though treating Venasquite as only a variety of Ottrelite, Dana‡ gives different formulae for the two, viz.:—

Ottrelite	..	..	..	$\text{H}_2\text{O}.\text{(Fe,Mn)O}.\text{Al}_2\text{O}_3.2\text{SiO}_2$
Venasquite	..	..	..	$\text{H}_2\text{O}.\text{FeO}.\text{Al}_2\text{O}_3.3\text{SiO}_2$

This difference in silica, if established, should give to each separate specific rank, or at least lead to the conclusion that Venasquite and Chloritoid were completely isomorphous and capable of inter-crystallisation. Turning, however, to the published analyses we find that, allowing for the isomorphous replacement of some iron by manganese, the compositions are identical, and conform to that given above for Venasquite, see Table I.

† Phyllite has priority, but is objectionable as being a name well established as that of a rock type.

‡ System of Mineralogy, p. 642.

TABLE I.
Comparison of Typical Minerals of Chloritoid Series.

Mineral.	H ₂ O.	SiO ₂ .	Al ₂ O ₃ .	FeO.	MnO.	MgO.
Ottrelite (Clarke)						
Venasquite (Dana)						
H ₂ O.FeO.Al ₂ O ₃ .3SiO ₂ ..	4.9	48.4	27.4	19.3	..	..
Ottrelite (Dana, Van Hise)						
H ₂ O.FeO.Al ₂ O ₃ .2SiO ₂ ..	5.8	38.5	32.7	23.0	..	..
Ottrelite (Rosenbusch)						
Chloritoid (Dana, Hintze, etc.)						
H ₂ O.FeO.Al ₂ O ₃ .SiO ₂ ..	7.1	23.9	40.5	28.5	..	..
Venasquite, Venasque ..	4.93	44.79	29.71	20.75	(?)	.62
Ottrelite, Ottrez ..	5.66	43.34	24.63	16.72	8.18	..
Chloritoid, Kossoibrod ..	6.34	23.01	40.26	27.40	..	3.97
Salmite, Vielsalm ..	7.44	22.52	39.60	15.35	8.40	2.10
				Fe ₂ O ₃ 3.97		
Sismondine, St. Marcel ..	6.56	26.03	42.33	14.32	..	7.30
				Fe ₂ O ₃ 4.09		

Dealing with analytical figures alone then, one would at first sight be led to the belief that in this series there were two distinct species Chloritoid and Venasquite characterised solely by their very different ratios of silica to bases, and that in each of these there has been recorded isomorphous replacement of the iron compound by minor amounts of the corresponding manganese compounds, sufficient to constitute sufficiently well marked manganese varieties of those species; further that in the case of Chloritoid, the iron compound may also be replaced by minor amounts of the magnesium compound, giving rise to a marked magnesian variety. In no case has the pure manganese or magnesium compound (that is H₂OMnOA1₂O₃.SiO₂ or H₂OMgOA1₂O₃.SiO₂ or H₂OMnOA1₂O₃.3SiO₂), been detected in nature, or even minerals in which these compounds preponderate over the iron compound, in either of which cases a new species would have been constituted. Attempts have been made to ascribe independent specific rank to ottrelite on the basis of its manganese contents solely, a position which is untenable in view of the constant molecular minority of this manganese component.

In spite of the apparent well marked distinction in composition between the type minerals of this series, there has always been much dispute as to the relative classification and even a doubt, to the present writer a well founded doubt, as to there being any real specific difference between Chloritoid and Ottrelite (Venasquite).

This doubt has largely been founded on the absolute identity of all physical properties, other than bulk specific gravity, of the two minerals, a most surprising condition to find existing between minerals so widely different in silica ratio, possessing at the same time identical ratios of other constituents.

Rosenbusch is most emphatic on this point. Under the heading "The Ottrelite Group," he says* :—

"Under the ottrelite group are here included the very closely related minerals called ottrelite, chloritoid, chlorite spar, masonite and sismondine. The name ottrelite is chosen for that of the group because it immediately suggests the geologically characteristic position of these minerals. The statements of the above cited authors regarding these minerals differ very widely, and cannot be altogether reconciled. The following (uniform set of, E.S.S.) data. . . . are derived from the study of ottrelite from Serravezza, from Ottrez, and St. Hubert in the Ardennes Mountains, of sismondine from Preggratten, Tyrol, and St. Marcel, Piedmont, of chloritoid from Kossibrod, Urals, Harvey Hills near Leeds, and Inverness in Canada and of masonite from Natic, Rhode Island."

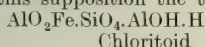
The only important omission from the series of occurrences examined by Rosenbusch is Venasque. After study of the numerous other typical occurrences of the various subspecies of this group, Rosenbusch is led to formulate an exhaustive list of optical and other physical properties which are identical for all the various subspecies of both chloritoid and ottrelite, and which are shared by the minerals found in Western Australia at Kalgoorlie and Yampi Sound.

Zirkel, after an examination of a large number of occurrences, mostly other than those examined by Rosenbusch, comes to the same conclusion,† viz., that

"All these minerals appear to exhibit no essential difference but to belong together, and the so-called masonite must also be included with them."

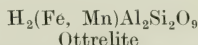
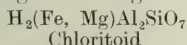
F. W. Clarke, on the other hand, is led to a different conclusion. He says‡

"Chloritoid has the formula $H_2FeAl_2SiO_7$; but that of ottrelite is not certain. The best evidence goes to show that the two minerals are alike in type, except that chloritoid is an orthosilicate, and ottrelite a trisilicate. On this supposition the two formulæ become :—



. . . . Ottrelite and chloritoid are probably often confounded."

Van Hise too§ considers ottrelite to be specifically different from chloritoid in containing one additional molecule of silica, the formulæ given being :—



The details given by Rosenbusch and others are tabulated for convenience of comparison in Table II. below, whilst the optical properties are also shown graphically in Plate VIII.

* Rosenbusch—Iddings: Microscopical Physiography of the Rock-making Minerals, 4th Edit., p. 289.

† Zirkel: Lehrbuch der Petrographie, I., 349.

‡ F. W. Clarke, Data of Geochemistry, 2nd Edit., p. 585.

§ C. R. Van Hise, Treatise on Metamorphism, p.p. 196, 199, 344.

TABLE II.

Comparison of Recorded Properties of Chloritoid and Ottrelite.

Property.	Chloritoid.	Ottrelite.
Occurrence ..	Almost exclusively confined to phyllitic schists (R.)	Almost exclusively confined to phyllitic schists (R.)
Habit	Scattered porphyritic, hexagonal or rounded disc-like grains or tufted aggregates	Scattered porphyritic, hexagonal or rounded disc-like grains or tufted aggregates.
Crystalline System	Monoclinic (R., C., H.) .. Triclinic (K. and L., D.)	Monoclinic (R., H.) Triclinic (D.)
Twinning	Polysynthetic parallel to (001) common	Polysynthetic parallel to (001) common
Cleavage	Basal, distinct. Prismatic with angle 120°, less distinct.	Basal, distinct. Prismatic with angle 120°, less distinct.
Hardness	6 to 7; Brittle	6 to 7; Brittle
Specific Gravity ..	Mean, 3·54 (M.) Kossoibrod, 3·55 Other localities— 3·36 (Zermatt) to 3·61 (Vermont)	Mean, 3·30 (M., V.H.*), 3·53–3·55 (R.) Ottrez, 3·3 (Dx.) Venasque, 3·26 Serpont, Lermieux, 3·27
Optical Properties	Biaxial Axial angle, 2E, 100°–118° Birefringence, positive, weak, 0·015 (M.) Mean Refractive Index, 1·72 (M.) Angle bet. c and Bxa, 12°–18° (R.) Absorption Scheme (R., D., Z.)— a, olive green b, plum- to indigo blue c, yellowish green .. Tschermak, in error, gives for Pregratten Chloritoid and Masonite— a, plum blue b, olive green c, oil green † Pleochroism, strong as above, but for Styrian Chloritoid very weak (F.)	Biaxial Large, variable. Birefringence, positive, weak, 0·015 (M.) 1·73 (M.) 12°–18° (R.) (R., D.) a, olive green b, plum to indigo blue c, yellowish green (R., D.) Tschermak, in error, gives for type Ottrelite same scheme as for Chloritoid Pleochroism, strong as above, but for Ottrez Ottrelite somewhat weaker (Dx.)

* Van Hise gives 3·545 as the specific gravity of both chloritoid and ottrelite in his Treatise on Metamorphism on pp. 196 and 199, but on p. 344, 3·52 to 3·57 (mean 3·545) for chloritoid only, and 3·3 for ottrelite. The tabulated figures on pp. 196 and 199 contain, however, several other curious errors, *e.g.*, 707·36 instead of 70·74 for the molecular volume of chloritoid; 620·37 instead of 312·34 for the molecular weight of ottrelite (assuming the ratio of Fe to Mn to be 2 to 1), etc. These figures lead to the entirely erroneous conclusion that ottrelite has a less molecular volume than chloritoid.

† Lacroix again, according to Zirkel, gives a third plainly erroneous scheme in which a and c are transposed.

TABLE II.—*continued.*

Property.	Chloritoid.	Ottrelite.
Composition ..	$\text{H}_2\text{O}(\text{Fe, Mg})\text{O}.\text{Al}_2\text{O}_3.\text{SiO}_2$ (D., H.) $7\text{H}_2\text{O}.7\text{FeO}.8\text{Al}_2\text{O}_3.8\text{SiO}_2$ (H., Sismondine) $\text{AlO}_2\text{Fe}.\text{SiO}_4.\text{AlOH}.\text{H}$ (C.) $\text{H}_2\text{O}.\text{FeO}.\text{Al}_2\text{O}_3.\text{SiO}_2$ (R.)	$\text{H}_2\text{O}(\text{Fe, Mn})\text{O}.\text{Al}_2\text{O}_3.2\text{SiO}_2$ (D., VH., Ottrelite) $\text{H}_2\text{O}.\text{FeO}.\text{Al}_2\text{O}_3.3\text{SiO}_2$ (D., Venasquite) $\text{AlO}_2\text{Fe}.\text{Si}_3\text{O}_8.\text{AlOH}.\text{H}$ (C.) $\text{H}_2\text{O}.\text{FeO}.\text{Al}_2\text{O}_3.\text{SiO}_2$ (R.)

Authorities: C., F. W. Clarke; D., Dana; Dx., Descloiseaux; F., Foullon; H., Hintze; K. and L., Keller and Lane; M., Miers; R., Rosenbusch.

The essential points to be decided in determining whether the two minerals are to be looked upon as different species are:—

- (1.) Have they, after allowing for minor isomorphous replacements, a different chemical composition;
- (2.) Have they, neglecting mere habit, a different crystalline form.

The former point requires a close analytical examination made with due regard to the laws of isomorphism, as well as to the purity of the material analysed. The latter requires, in the absence of reliable angle measurements, investigation of the optical properties and specific gravity.

Turning to Table II., it is evident that in physical properties there are many points of absolute identity, but that there has been some uncertainty as to the crystalline system and absorption scheme, and further there is an apparent divergence in composition.

Dealing first with those points which affect the crystalline form. There is still an element of doubt as to whether both minerals are truly monoclinic, or both triclinic, though very close in symmetry to the monoclinic system. The claims upon which the latter supposition rest are those of Descloiseaux for the Italian chloritoid (sismondine) which are:—

- (1) The angle between cleavage traces and (010) measured on the basal plane are not identical, viz. 62deg. and 58deg.;
- (2) The axial plane is not exactly parallel to (010) but inclined to it at an angle of 1deg. to 1deg. 30min.;
- (3) Dispersion is greater for one axis than for the other.

In view of the difficulties attendant on determining such small differences on such imperfectly crystallised material, both Hintze and Rosenbusch entirely discount Descloiseaux determinations and class both minerals together as one monoclinic species. Neither axial angle or axial ratios have been determined for either mineral. Whilst the former appears to approximate closely to 90deg., the large optic axial angle and distinct inclination of the acute bisectrix to the

vertical axis, viz., 12deg. to 18deg. or more, in each case, leave no doubt as to the system being either monoclinic or triclinic extremely close to monoclinic. In either case there is absolutely no difference between the two minerals.

Turning to the disputed differences in absorption scheme: Rosenbusch is emphatic that there is but one absorption scheme for all species of ottrelite and chloritoid. Tschermak, who gives an abnormal scheme for the chloritoid of Pregratten and the masonite of Rhode Island, gives the same abnormal scheme for ottrelite. Even Tschermak therefore finds identity between some chloritoid and ottrelite. There can be little doubt that this abnormal scheme, which differs from the normal in a transposition of the transmitted colours for the rays vibrating in a plane vicinal to the basal plane, is incorrect, and arose from insufficient allowance being made for the prevalent polysynthetic twinning on that plane.

In the case of the minerals from Yampi and Kalgoorlie in this State the following scheme was determined for both:

- a, Deep grass green
- b, Slate blue
- c, Pale amber yellow

Apart from slight differences in tint, this scheme agrees with that of Rosenbusch.

It should be observed that in preparing an absorption scheme for such a poorly crystallised mineral recourse must often be had to the irregularly oriented sections of a rock slice. In such a slice the colour of this mineral along c, a pure pale amber yellow, is only seen when the section is absolutely parallel to the plane cb or ca, any inclination of the plane of section, however slight, introduces some of the strong green or blue of a or b and gives to the light vibrating in the plane of the acute bisectrix (*i.e.* normal to the trace of the basal plane in a section parallel to the plane cb, or at an angle of + or -70deg. to 78deg. to the trace of the basal plane in a clinopinacoid section) a more or less distinct green tint. Similar, but less marked, interference must be guarded against in observing the colours along a and b.

Some slight differences in the strength of the pleochroism have been noted by some authors. In dealing with this question allowance must be made for the varying isomorphous replacement of the typical iron-bearing molecule by the corresponding magnesium or manganese one. In a mineral of this type the strength of pleochroism is approximately directly proportional to the percentage of iron, *cf.* tremolite and actinolite, enstatite and hypersthene, etc. Further, the replacement of alumina by ferric oxide similarly increases the pleochroism, *cf.* ferruginous and non-ferruginous epidote. The substitution of manganous oxide for ferrous oxide usually weakens the pleochroism of minerals but the effect of manganic oxide is not known. In such a mineral as chloritoid or ottrelite subject to the replacement of FeO by MnO or MgO, and of Al_2O_3

by Fe_2O_3 and possibly Mn_2O_3 , slight variations in strength of pleochroism are to be looked upon as normal phenomena in no way connected with specific differences in crystalline form or composition.

Whilst in the case of two otherwise apparently similar minerals a difference in specific gravity may be due to varying molecular volume accompanied by differences in form (*e.g.* rutile and octahedrite), such a difference is more often due to isomorphous replacements by a molecule of similar volume but different molecular weight (*e.g.*, in the tantalite and columbite series) or to invisible inclusions of foreign minerals of different specific gravity. As will be seen below, it is to the latter cause that one must attribute the differences in specific gravity between the lightest ottrelite, 3.26, and the heaviest chloritoid, 3.61.

To sum up, one may say that no case has been made out for considering that typical chloritoid and typical ottrelite show any specific difference in crystallisation, on the contrary everything points to a complete identity in crystalline form and of properties dependent upon it.

Turning now to the chemical composition, we are faced at once with very varying percentages in the silica shown by analyses. In Hintze's table,* which is the most complete, the silica percentage ranges from 23.01 to 44.79, though in 28 out of 38 analyses the silica is below 30 per cent., which represents a ratio of SiO_2 to FeO of 1.37 to 1. Relying on these analyses as being made on pure material, we find:

Dana, Chloritoid; Clarke, Chloritoid, $\text{H}_2\text{O}.\text{FeO}.\text{Al}_2\text{O}_3.\text{SiO}_2$.

Dana, Ottrelite, $\text{H}_2\text{O}.\text{FeO}.\text{Al}_2\text{O}_3.2\text{SiO}_2$.

Dana, Venasquite; Clarke, Ottrelite, $\text{H}_2\text{O}.\text{FeO}.\text{Al}_2\text{O}_3.3\text{SiO}_2$.

There can be but little doubt but that, if chloritoid and ottrelite are distinct species, as these formulæ indicate, they are completely isomorphous. Dana's ottrelite would then simply be a solid solution of chloritoid and venasquite (Clarke's ottrelite). Clarke adopts this view, assuming that SiO_4 and Si_3O_6 are mutually replaceable constituents of two completely isomorphous compounds. This assumption in the case of other silicates has been challenged by H. S. Washington.† It is certainly contrary to modern accepted theories of isomorphism, and as there are no proved instances of its truth in regard to other series of minerals, it should not therefore be resorted to as an explanation until the source of the whole of the silica shown in the analyses has in each case been placed beyond doubt.

Briefly put, the question is, are chloritoid and ottrelite possessed of different compositions or is the so-called ottrelite merely a mixture of chloritoid with granules of quartz or of a highly siliceous

* C. Hintze, *Handbuch der Mineralogie* II., 677.

† H. S. Washington, *The Constitution of some Silicic Silicates*, A. J. S., XXXIV, 563.

silicate. There can be little doubt that the latter of the two alternatives is the true one.

Genetically chloritoid belongs to a series of secondary minerals including garnet, andalusite, staurolite, and iolite, which develop in large or moderately large crystals under conditions of prolonged static metamorphism in more or less fine-grained rocks, composed of a large number of original minerals only part of which contribute to the growth of the secondary mineral. A marked peculiarity exhibited by all these minerals is their tendency to enfold in their growth numerous "undigested" grains of the original rock constituents. The tendency of andalusite to envelope carbon and carbonaceous matter is known to every student, and in a similar way garnet encloses much graphite (*e.g.*, at Marvel Loch, W.A.) or quartz (*e.g.*, at Northampton, W.A.), and staurolite very commonly encloses abundant quartz, as illustrated in Luquer's "Minerals in Rock Sections," p. 72, where the mineral is shown enveloping quite 40 per cent. of the total volume of granular quartz. Normal staurolite should contain about 27 per cent. of silica, but analyses show percentages rising from that figure to 51 per cent., with corresponding decreases in bulk specific gravity. No one has, however, suggested that the species staurolite should be divided into two or more on the basis solely of the silica percentages.

In view of the above facts one is led to inquire closely into the possibility of the varying and sometimes high percentage of silica in chloritoid-ottrelite being due merely to inclusions of quartz as in staurolite.

Dana says of ottrelite* :—

"The formula, however, is doubtful because of the difficulty of obtaining pure material, free from inclusions, for analysis."

Hintze, describing various occurrences, says† :—

"Saxony, . . . ottrelite plates . . . strongly permeated by quartz and haematite; crystals more or less contaminated by inclusions, in a coarsely granular schist close to Lower Rabenstein . . . Belgium, "Ottrez, . . . The impurity of the material was shown by Fischer, von Renard, and de la Vallée Poussin, a filling with dark, perhaps coaly particles and numerous quartz inclusions. . . . Rhode Island, Natic, . . . Among the very large number of foreign inclusions biotite scales predominate."

Zirkel says‡ :—

"Microscopic inclusions of quartz grains, rutile prisms, tourmaline needles, biotite scales, iron ore and carbon particles are very plentiful."

Rosenbusch writes§ :—

"The chemical composition is not definitely known, because of the difficulty of removing the abundant interpositions. . . . The rock-making ottrelite minerals generally contain a great many different interpositions, among which are quartz grains, ores, carbonaceous particles, rutile needles, and tourmaline columns."

* Loc. cit., p. 642.

† Loc. cit., pp. 671-4-5.

‡ Lehrbuch der Petrographie, I., 348.

§ Loc. cit., p. 292.

In the illustrations of ottrelite from Ottrez in Plate XXI. of Rosenbusch's work innumerable inclusions of quartz are to be seen.

Finally, Van Hise* mentions the strong tendency of "porphyritic" crystals of chloritoid in the schists to envelope numerous granules of original minerals, especially quartz, a fact illustrated in Fig. D., Plate III., of chloritoid from the Black Hills of South Dakota.

All the foregoing facts and verbal contradictions were in the present writer's mind when describing briefly in Bulletin 42 of this Survey† the occurrence of a mineral of this group at Kalgoorlie under the name of Ottrelite (following Rosenbusch). This mineral was, however, in such small crystals, 0.5 to 1.0 mm. in diameter, and the amount of material available was so limited, that it was impossible at that time to make a critical study of the composition. Later, however, a small amount of a mica schist with much larger chloritoid crystals, viz. 2 to 4 mm. in diameter, was received from Yampi Sound, West Kimberley, where it had been collected by a prospector

Fig. 5.

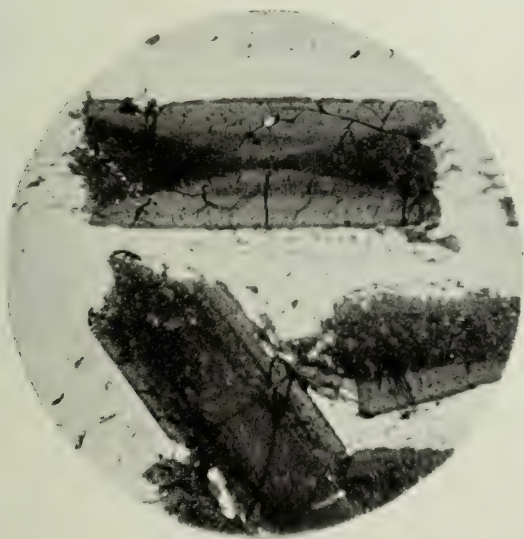


Photo., H. Bowley.

Neg. 1212.

Chloritoid in Mica Schist, Yampi Sound.

Enlargement, $12\frac{1}{2}$ diameters.

under the impression that it was tin ore. As opportunity offered this material was examined physically and chemically with a view to throwing light on the relationship between ottrelite and chloritoid.

* Loc. cit., pp. 701-4.

† E. S. Simpson and C. G. Gibson, G.S.W.A., Bull. 42, Contributions to the study of the Geology and Ore Deposits of Kalgoorlie, p. 142.

The ground mass in which the mineral occurs at Yampi Sound is irregularly banded and strongly foliated. It is composed of finely granular quartz, muscovite, chlorite, magnetite, rutile, and tourmaline, in this order of frequency, the two first named being very abundant, the last named rare and in very small scattered prisms. The chloritoid is in abundant flat black discs usually about 3 mm. in diameter and a little under one millimetre in thickness. These discs, which form a striking feature in the hand specimens, are much more plentiful in some bands than in others, and are quite irregularly oriented. The appearance of the mineral and ground-mass under the microscope is shown in Fig. 5. The mineral is very dense in moderately thick sections, particularly basal ones. In thin sections it is strongly pleochroic, the axial colours being: *a*, rich grass green; *b*, slate blue; *c*, (*Bxa*), pale amber yellow. Inclusions are very plentiful, but most capriciously distributed both as regards crystal individuals and different portions of the same individual. No crystal as a whole appeared to contain less than 5 per cent. by volume of inclusions, whilst most of them contained much more, and many not less than 30 per cent. Their distribution within the individuals is noteworthy. By far the greater proportion of the interpositions are congregated within a space the shape of a double concave lens lying centrally in the crystal, with its diameters in the basal plane. This is well illustrated in Fig. 5. Within this space the inclusions may amount to as much as 40 per cent. by volume of the whole mass, whilst in the outer portion the proportion is usually only 2 or 3 per cent. This arrangement is very persistent and characteristic. It bears no relationship whatever to the invariable polysynthetic basal twinning; see Plate VII., Fig A.

An overwhelming number of inclusions consist of quartz grains with curved outlines, varying in size from 1 to 100 μ . Their appearance is seen in Plate VII., Fig B. Other inclusions noted were deep yellow prisms of rutile and very fine black dust which may be magnetite. Neither of the latter formed any considerable proportion of the whole crystal.

In preparing material for analysis, one must take into consideration not only the true inclusions but also the extraneous matters interlocked with the invariably ragged edges of the crystals in the zone [001]. See Fig. 5. The most important of these were found to be quartz and mica. For the analysis a number of discs weighing in all about 6 grammes were broken out by hand and alternately subjected to a prolonged shaking in a small strong bottle, and then separated on a 30-mesh sieve from the resultant dust. This process was repeated several times and resulted in the abrasion of the ragged edges of the chloritoid with their interlocked foreign matter, which was removed by the sifting. After this treatment any crystals which were still visibly contaminated were rejected and the balance crushed to pass a 30-mesh screen and then treated with a

PLATE VII.

Fig. A.

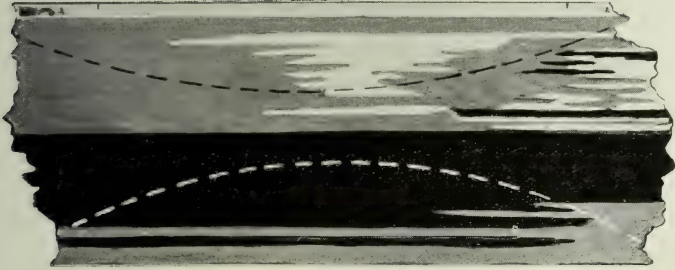


Fig. B.

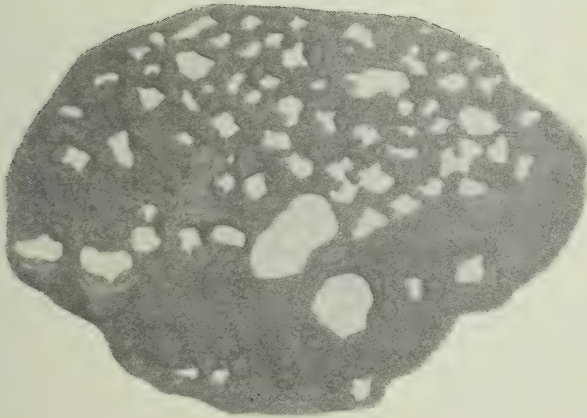
**Chloritoid, Yampi Sound.**

Fig. A.—Vertical section, showing polysynthetic twinning on basal plane. The portions similarly shaded extinguish simultaneously. The dotted lines give the outer limits of the denser mass of inclusions. Enlargement, 30 diameters.

Fig. B.—Basal section, showing quartz inclusions. Enlargement, 60 diameters.

heavy solution to ensure uniformity of composition in the material analysed. Owing to the high specific gravity (3.55) of pure chloritoid, the only solution available was silver thallium nitrate, with which it was found that most of the cleaned material had a density ranging between 3.40 and 3.47. Any fragments which floated at 3.40, and the few which sank at 3.47 were rejected. This variability in density was only to be expected in view of the varying proportions of inclusions noted in the microscopic examination. Owing to the opacity of the mineral it is not feasible to examine in detail under the microscope each crystal used in an analysis.

The analytical results obtained are given in Table III.

TABLE III.
Analytical Results, Yampi Chloritoid.

—		Actual Results.	First Recalculation.	Second Recalculation.	
		per cent.	per cent.	per cent.	molecules.
TiO ₂ (Rutile) ..		54	54	..	..
SiO ₂ (Quartz) ..	} 31.40 {		9.50	..	..
SiO ₂ (Combined) ..			21.90	24.31	403
Al ₂ O ₃		35.29	35.29	39.18	383 } 405
Fe ₂ O ₃		3.21	3.21	3.56	22 } 403
FeO		20.39	20.39	22.64	315 } 403
MnO		1.36	1.36	1.51	21 } 403
MgO		2.43	2.43	2.70	67 } 403
CaO		trace	trace	trace	..
H ₂ O		5.99	5.99	6.65	369
		100.61	100.61	100.55	
Spec. Grav. ..		3.40-3.47	3.44*	3.55†	

* Calculated density of the mixture of rutile, quartz, and chloritoid.

† Calculated density of the pure chloritoid free from inclusions.

Analyst E. S. Simpson.

This table is to a large extent self-explanatory. The whole of the TiO₂ is assumed on good grounds to be present as included rutile. Of the silica, 9½ per cent. is assumed to be present as free quartz on three grounds, viz.:—

(a) With this assumption the ratios of the molecules SiO₂, Al₂O₃, and FeO become 1 to 1 to 1, which is that in normal chloritoid, without it the ratios are 1.29 to 1 to 1, which are indefinite and not those of any known mineral;

(b) Because of the observed inclusions of quartz under the microscope, 9.50 per cent. by weight of quartz would be 12.31 per

CRYSTALLOGRAPHIC CONSTANTS OF CHLORITOID

Fig A.

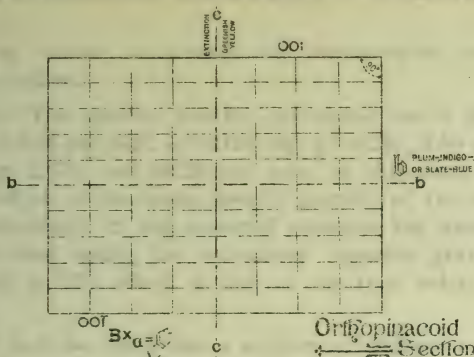


Fig B.

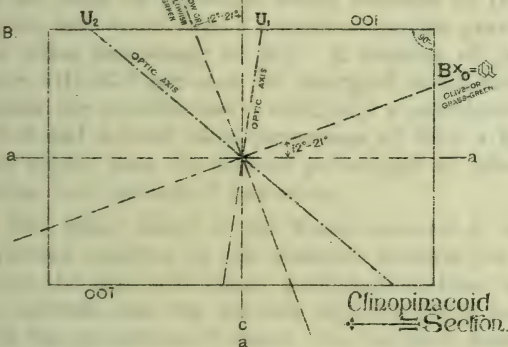
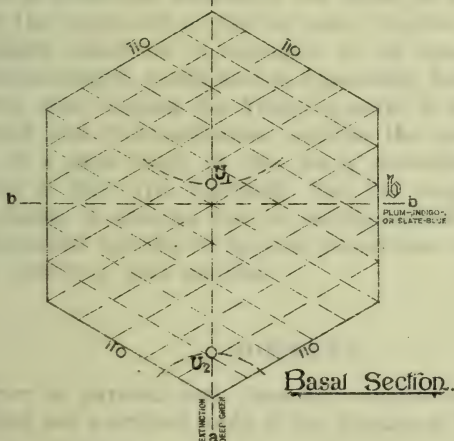


Fig C.



CRYSTALLOGRAPHIC AXES

AXES OF ELASTICITY

OPTIC AXES

CLEAVAGES

CRYSTALLOGRAPHIC CONSTANTS OF DIFLUORIDE



1100
1100
1100



1100
1100
1100



1100
1100
1100

cent. by volume, an average not unreasonable, judging by the sections studied.

(c) The specific gravity calculated for a mechanical admixture of 0.54 per cent. of rutile (sp. gr. 4.20), 9.50 per cent. of quartz (sp. gr. 2.65), and 90.26 per cent. of chloritoid (sp. gr. 3.55) is 3.44, which is the mean specific gravity of the material analysed. Or conversely, if the material contains the assumed amount of quartz and rutile, the calculated specific gravity of the pure mineral is 3.55, which is that of the type chloritoid from Kossoibrod.

It is to be noted that a mixture of 19.2 per cent. of quartz with 80.8 per cent. of chloritoid would conform to Danas formula for ottrelite and would have a calculated specific gravity of 3.33 and a total silica percentage of 38.5. A mixture of 32.3 per cent. of quartz with 67.7 per cent. of chloritoid would conform to Clarke's formula for ottrelite and would have a calculated specific gravity of 3.20 and a total silica percentage of 48.4, a figure nearly four units higher than the highest percentage of silica ever found by analysis in a mineral of this series.

The water found in the Yampi mineral is below the normal proportion required by the accepted formula for chloritoid. This is also the case with many published analyses of chloritoid and may indicate that the formula requires slight modification as regards the proportion of water. On the other hand, it is extremely difficult to determine accurately the water in such a mineral, and usually the results err on the low side. Further, there is probably some slight admixture of magnetite in the material analysed, and this contamination would lead to apparently low results for water. In every other respect the Yampi mineral is undoubtedly typical chloritoid, and its examination confirms the opinions formed as a result of a close study of the many published descriptions of minerals of this type, especially that the varying proportions of silica shown in analyses and the varying specific gravity are mutually dependent and due to varying proportions of quartz inclusions in the otherwise pure mineral.

SUMMARY.

From a physical and chemical examination of the Yampi chloritoid and a critical study of the literature, I am led to the following conclusions:—

- (1.) That there is no specific difference between Chloritoid and Ottrelite;
- (2.) That both minerals possess the general formula $H_2O.FeO.Al_2O_3.SiO_2$, and are identical in crystallisation;

- (3.) That the more siliceous minerals which have from time to time been described are simply intergrowths of Chloritoid and Quartz;
- (4.) That three varieties of the species are recognisable, viz.:—

Normal Chloritoid		..	$\text{H}_2\text{O}.\text{FeO}.\text{Al}_2\text{O}_3.\text{SiO}_2$
Manganiferous Chloritoid, Ottrelite	..	..	$\text{H}_2\text{O}.\text{(Fe,Mn)O}.\text{Al}_2\text{O}_3.\text{SiO}_2$
Magnesian Chloritoid, Sismondine	..	..	$\text{H}_2\text{O}.\text{(Fe,Mg)O}.\text{Al}_2\text{O}_3.\text{SiO}_2$

The isomorphous replacement of ferrous oxide by manganese or magnesium oxide is always a minor one, and does not, therefore, lead to the establishment of new species.

- (5.) That Venasquite is identical with normal chloritoid, and Salmite with ottrelite (*vide* p. 65).
- (6.) That the mineral occurring at Yampi Sound is normal Chloritoid, but the mineral at Kalgoorlie not having yet been separated and analysed, may be either Normal Chloritoid or the manganesian variety Ottrelite, since the analysis of the containing rock, as a whole, shows a considerable proportion of manganese.

3rd December, 1914.

58.—THE GEOLOGY OF WESTERN AUSTRALIA.*

By A. GIBB MAITLAND.
With a Map. Plate IX.

CONTENTS.

	Page
Introduction	79
Physiography	80
Systematic Geology	82
Economic Geology	90
References	91

INTRODUCTION.

The State of Western Australia is one, and the largest, of the divisions of the Commonwealth, though it does not constitute a natural geographical region. It occupies, as its name implies, the Western portion of the Continent, and embraces an area of 975,920 square miles out of the 2,974,581 which make up the whole area of the Commonwealth. Western Australia lies between the 14th and 34th parallels of South latitude, though when viewed broadly it does not present any very great variety in its physical features.

Geological investigation in the State has, up to the present, consisted chiefly of a series of more or less unconnected observations, for the co-ordination of which we must look to the future. Despite this circumstance, it has now been found possible to obtain a bird's eye view of the salient geological features of Western Australia.

In the broad area of the State pretty nearly all geological systems have representatives in the rocks. In general the Pre-Cambrian rocks, which occupy about one-third of the superficial extent of the State, are found chiefly in the South-Western portion of the State, and in scattered areas North of latitude 26°. The Palæozoic systems are best known in the northern and the eastern interior, though they are also met with in the Irwin River valley to the north of Perth. The Mesozoic Rocks are exposed chiefly in the maritime districts of the State in the North-West, West and

*Written for the Australian visit of the British Association for the Advancement of Science, 1914, and for a general account of the Geology of the Mining Fields of the State, *vide* No. 59 *ante*.

South. The Tertiary and recent formations form a narrow fringe along the coast and have their widest distribution in the westernmost portion of the country.

Dr. F. von Sommer was the first official geologist employed in Western Australia, and held office from 1847 to 1851. Neither the maps nor the reports of Dr. von Sommer have ever been published, although some articles from his pen appeared in the current literature during the years 1848 and 1849. The original drawings of Dr. von Sommer's maps were discovered some years ago, and are preserved in the historical collection of the survey showing the progress of geological mapping in Western Australia, which is now on view in the Geological Survey Office.

After an interval of 21 years, during which much excellent geological work was accomplished by the Gregory Bros., Mr. H. Y. L. Brown was appointed to the post of Government Geologist. This gentleman during the years 1870 to 1873, prepared three geological maps and ten reports, dealing principally with the southern and maritime portions of the State. In 1882, Mr. E. T. Hardman, of the Geological Survey of Ireland, was appointed Government Geologist, and his labours were confined chiefly to the Kimberley Division, in which he was the pioneer geological observer; his field work, carried out during the years 1883-4, laid the foundations of our knowledge of the geology of the tropical portion of Western Australia, and played an important part in the opening up of the State's first goldfield. The late Rev. C. G. Nicolay, Chaplain to the Fremantle Gaol, contributed in very many ways to the knowledge of the geology of the State, and was officer-in-charge of the Geological Museum at Fremantle, which was founded by Mr. Hardman, and which ultimately became merged into the Western Australian Museum. In 1887 the position of Government Geologist was conferred upon Mr. H. P. Woodward, who held the position from 1887 to 1895. With a very limited staff, and still more limited appropriation, and in spite of the difficulties presented by the vast area of the State, the survey under Mr. Woodward issued 21 reports and six geological maps. It was during this period that the paramount necessity for **"the publication of reliable geological knowledge relating to the nature and extent of useful mineral deposits, supplemented by geological maps and plans,"** was impressed upon the Government by its scientific advisers.

The work of organising a more or less systematic geological survey was entrusted to the writer in 1896, and had for its object the investigation of the geological structure, mineral and allied resources, and underground water supplies of the State.

PHYSIOGRAPHY.

Physiographically considered the State of Western Australia falls naturally into three fairly well-marked subdivisions, viz.:—

The Coastal Plain, the Hill Ranges, and the Plateau and Plains of the Interior. Each of those subdivisions is comparatively well-defined, though the line of separation cannot always be very sharply drawn, owing to the blending of one subdivision with another; hence the boundaries can only be spoken of as occurring within certain limits.

For purposes of description the State may also be divided into six geographical divisions, viz.:—The Northern or Kimberley, the North-West, the South-West, the South-East or Eucla, the Central or Salt Lake, and the Eastern Divisions. The boundaries of these divisions are fairly well marked.

The Coastal Plain consists in reality of a fringe round the coast with a more or less gentle slope to the seaward. The plain has a width of 60 or 70 miles in places on the Western Coast, though in the country at the head of the Great Australian Bight it extends some 200 miles into the interior, and is absolutely devoid of rivers. The inner margin of the Coastal Plain reaches an altitude of 600 feet above sea level in certain localities. The line of demarcation of the Coastal Plain, and the hill ranges on the east, is marked by what is termed the Darling Fault Scarp, averaging about 1,000 feet in height and traceable to the North and South of Perth for over 300 miles. The western limit of the Coastal Plain is at the edge of the continental shelf, which is located a great many miles off the shore at a depth of about 100 fathoms below the surface of the Indian Ocean. This is in reality the submerged border of the Western portion of the Australian Continent, which extends seawards with a gradual slope to the 100 fathom line.

The Coastal Plain may thus be divided into a submarine and a subaerial division, the line of demarcation between which is the sea shore. The subaerial division is itself separable into the Western and South-Western portion, the latter comprising the Eucla Limestone Plateau or the Premier Downs, traversed by the Transeontinental Railway, now in course of construction. The average altitude of the northern or inland margin of this plain is about 1,000 feet above sea level. The rainfall is very slight, except near the coast, and no rivers enter the sea, anywhere, for 400 miles west of Eucla, on the South Australian border.

By far the greater portion of the State is in reality a very extensive plateau averaging about 1,400 feet in height, though isolated portions reach altitudes approaching 4,000 feet. The interior portion of the plateau has a very restricted and limited rainfall and is drained by intermittent water courses, which debouch into shallow basins, generally known as "Salt" or "Dry" lakes. Wind erosion is the predominating agent in the formation of these salt and dry lakes, and also the greatest denuding agent which tends to keep the plateau level. The plateau which forms the chief

mineral region of the State, is mantled by superficial deposits concealing the underlying rocks over very wide areas.

A large portion of the Kimberley and North-West Divisions consist of a dissected plateau built up of horizontal or gently inclined strata, and possesses in general all the familiar scenic features of such formations. This dissected plateau is drained by the principal rivers of the State, many of which extend for some hundreds of miles inland, and some of which flow through cañons of great extent and exceptional beauty.

There are no folded and little denuded mountain chains in Western Australia; such as do exist owe their origin either to block faulting or result from erosion.

The coast line is extensive and generally has a smooth irregular outline, though portions are broken and indented and fringed with numerous islands and archipelagoes. The very much indented coast line of the Kimberley Division is due to the drowning of the river valleys, of which the Prince Regent River, falling into Brunswick Bay, is the most typical example.

SYSTEMATIC GEOLOGY.

One of the most pronounced features in the geology of the State is the very marked diversity between the western and the eastern portion of the Australian Continent, and the very remarkable similarity in structure and constitution to that of India, South Africa, and Madagascar. This noteworthy resemblance is paralleled not only in the Pre-Cambrian Rocks, but also in the Palæozoic and Mesozoic Beds.

PRE-CAMBRIAN, ARCHAEOAN (?).—The oldest known rocks of Western Australia comprise a great group of crystalline rocks, which almost everywhere constitute the foundation of the State. There are huge tracts over which sedimentary strata effectually conceal the crystalline rocks. To the whole of these rocks, however, observers have invariably assigned an Archaeozoic age; but this is rather inferred than proved. In the absence of any other evidence it has been found convenient to separate the crystalline rocks of the State into two great lithological groups, viz., (a) gneissic, granitoid, and schistose rocks, and (b) a group of conglomerates, quartzites, phyllites, schists and soft felspathic and micaceous gneiss, associated with basic rocks, which have been at times converted into greenstone schists. The rocks have been more or less irregularly folded along highly inclined axial planes; the folding is meridional, the prevalent strike being generally north-west and south-east.

Some of the hornblende rocks may possibly represent original gritty beds made up of epidote, chlorite, etc., and the magnetite hematite quartz-schists, referred to below, may perhaps have originally been ferruginous grits of sedimentary origin.

A remarkable and very noticeable feature of these older rocks is those bands of laminated cherts and jaspers, which often contain oxide of iron to such an extent as to warrant their being classed as iron-ores. These extend as roughly parallel bands, sometimes several miles in length, in the form of attenuated lenses, which, owing to their serrated ridges, stand out in bold relief, thus acquiring a conspicuousness out of all proportion to their real stratigraphical importance. These bands are often intersected by numerous faults, which in some districts are of considerable economic importance, for it is along these fault lines that rich shoots of gold often occur.

These older rocks are invaded by masses of veins of granite and allied rocks, which in many parts of the State occupy very large areas, sometimes embracing hundreds of square miles. The old granitic rocks are traversed by many large ice-like quartz reefs, which rise to considerable altitudes above the surface like a wall, and which can in some cases be traced across country with more or less interruption for miles. The mode of occurrence of these large quartz masses points to their being of igneous origin, representing the final product of the differentiation of a granitic magma—its ultra-acid portion.

There are probably few parts of the Australian continent which can boast of a finer development of these older rocks than Western Australia.

NULLAGINE SERIES.—Age undetermined. A formation which has been designated the Nullagine Series, and which cannot be exactly correlated with any defined geological horizon in Western Australia, has a very wide distribution in the North-West Division of the State. The series consist of a great thickness of sandstones, grits, conglomerates, and limestones, some of which are magnesian, together with a series of lavas, ashes, and agglomerates. The formation is of some economic importance, by reason of the fact that the basal members of the series have proved to be auriferous in two localities, viz., Nullagine and Just-in-Time.

The beds of the Nullagine Series make a very prominent feature in the landscape in the districts in which it is developed, and play a very important part in the geology of the North-West. The series may be followed from the Oakover River, across the upper reaches of the Nullagine, the Coongan, and the Shaw Rivers, as far as the western boundary of the Pilbara Goldfield on the Yule River, near Cangan Pool, from which locality it can be followed without a break to Roebourne, and southward to the Fortescue River. The same series constitutes the Hamersley Range, which contains Mount Bruce, the highest summit in the State.

In its lithological characters and general behaviour the Nullagine Series bears a very strong resemblance to the quartzites, etc., which constitute that continuous formation which extends from

Wyndham to Mount Hart, a prominent summit in the King Leopold Range in the Kimberley Division. This formation as developed in Kimberley consists of a series of quartzites, sandstones, fine conglomerates, and shales, disposed in a series of broad anticlinal folds. Associated with the sediments is a series of bedded and intrusive igneous rocks, some of which are distinctly amygdaloidal, and contain zeolites and agates in the cavities. Beds of volcanic ash and breccia are common in certain localities. In certain portions of the King Leopold Plateau are many excellent sections showing the intrusive nature of some of the igneous rocks. The sandstones are sometimes altered into hard compact quartzite, portions of which have been caught up in the body of the igneous rock. Other sections indicate quite clearly that some of the igneous rocks have found an easy passage along the bedding planes of the sedimentary rocks, and evidently occur in the form of sills. The lavas are traversed by almost vertical dykes of epidosite, which are traceable across country for long distances; while both the sedimentary and igneous rocks are intersected by numerous segregation veins of quartz some of which are of considerable size and horizontal extent.

The recognition of the position of the beds of the Nullagine Series in the stratigraphical succession is of considerable importance; the entire absence of fossils throughout the series renders correlation extremely difficult. The beds forming the King Leopold Plateau have been claimed by previous observers as being of Cambrian age. If the lithological and stratigraphical resemblance between beds of the King Leopold Plateau and those of the Nullagine Series, as developed in Pilbara and the Ashburton, should prove to possess greater significance than at present appears, a Cambrian age for the Nullagine Series would have strong claims to acceptance.

In its lithological characters and its structural relationships the Nullagine Series bears a very marked resemblance to that formation in South Africa known as the Potchefstroom or Transvaal System, which is Pre-Devonian in Age.

CAMBRIAN.—Strata of undoubted Cambrian age are known to occur in the Kimberley district, and were discovered by Mr. E. T. Hardman in 1883-4. In the course of his explorations this observer gathered a suite of fossils, amongst which were the head and spine of a trilobite belonging to the characteristic Cambrian family *Olenellus*, *O. Forresti*, and numerous Pteropods, *Salterella Hardmani*. These came from a locality which, unfortunately, cannot now be definitely identified. Despite the poor localisation of Mr. Hardman's fossils it may be considered as proved that Cambrian strata do occur somewhere in Kimberley about 18deg. southern latitude. The strata with which these fossils were associated consist of limestones, sandstones, quartzites, clayslates, and sandy flags. The superficial area, however, would seem to be extensive, for they have

been proved to extend in a north-east and south-west direction from the Burt Range and for some distance to the southward of Mount Dockrell. The strata have been tilted in such a way that the principal axis of folding is north-west and south-east. No estimate has yet been made of the thickness of these, the oldest fossiliferous beds yet found in Western Australia. The discovery of *Olenellus* and *Salterella* in the limestones of the Daly River, in the Northern Territory, is of considerable geological importance, indicating as it does a somewhat wide distribution of Cambrian strata in the northern portion of Australia.

SILURIAN (?)—The occurrence of strata of Silurian Age in Western Australia has been rather inferred than proved. Certain rocks occurring in the Mount Barren Range were described in 1861 by Mr. F. T. Gregory as probably belonging to this period, though the evidence upon which this determination was based was not given.

The strata forming the Stirling Range, which lies about 30 miles to the northwards of Albany, have been claimed as Silurian. The Stirling Range Beds form a grand chain of mountains, which lie not very far from the coast, and form one of the most conspicuous scenic features in the south-eastern portion of the State. The beds consist of quartzites, sandstones, and shales, the whole being traversed by quartz veins; they are highly folded, contorted, and faulted in places. The rocks at the western end of the Range, near Moondinup, have been thrown into three sharp anticlinal and synclinal folds, in a distance north and south of about ten miles, by a lateral compression from the south. The Stirling Range Beds bear a very remarkable resemblance to the Table Mountain Sandstone Series as developed in South Africa, which have been claimed as Devonian.

The strata chiefly developed in the King Leopold and Mueller Ranges of Kimberley have been provisionally classed by Mr. E. T. Hardman as Silurian, more on account of their lithological character than on any stratigraphical or palæontological evidence. The beds consist of pure crystalline quartzites, indurated grits, and quartzose conglomerates, interbedded with purple slates and soft sandstones. Much detailed field work is, however, required before the occurrence of undoubted Silurian rocks in Western Australia can be considered to have been definitely proved.

DEVONIAN.—The occurrence of Devonian rocks has as yet been definitely proved only in one district of the State—the Kimberley Division—where this formation appears to be largely developed. The beds consist of hard grits, conglomerates, indurated limestones, and shales, associated with which are contemporaneous lava flows, breccias, and ashes. In the Napier Range the Devonian rocks are represented by solid crystalline limestones, with at the base of the formation a calcareous breccia and conglomerate. These beds are seen in the Barker River Gorge to pass beneath a series of sandstones and shales of what is believed to be Carboniferous age.

Among the fossils found in the Napier Range beds are a *Coccostean* fish, a new species of *Proetus*; remains of *Loronema*, sp.; *Euomphalus*, sp.; *Rhynchonella*, allied to *R. Timorensis*; *Pachypora*, sp.; *Phillipsastraea*, sp.; and *Goniatites*, sp.; which clearly indicate a Devonian age for the strata.

The list of Devonian fossils of Western Australia will be found set out in Bulletin 50.

PERMO-CARBONIFEROUS.—The Permo-Carboniferous rocks cover a wide extent of country, and there are four regions in which the beds are known, viz., Kimberley, Gascoyne, Irwin River, and the Collie River. Wherever these Permo-Carboniferous rocks have been examined in Western Australia it has been found that the formation can everywhere be divided into a Lower or limestone series (in which limestones predominate), and an Upper or sandstone series (made up largely of sandstones and other sedimentary beds).

Interbedded with the Permo-Carboniferous rocks of the North-West and the Irwin River is a very persistent boulder bed, the component pebbles of which are covered with striæ of such a nature as to suggest that they owe their origin to ice action. Sections occur which show that this bed does not attain any great thickness, and that it is crowded with pebbles and boulders of granite, etc., embedded in a calcareous, fossiliferous matrix, which contains fragments of *Spirifera*, *Productus*, and *Polyzoa*, in addition to *Aviculopecten tenuicollis*. The fossil contents indicate a marine origin for the boulder bed. As it is convenient to have a name by which to designate this important geological horizon, it is proposed to use for it the term "Lyons Conglomerate," which is the official designation of the land district in which it was first discovered, and where it is so well developed. Whenever seen *in situ* it has been found that this glacial boulder bed (the Lyons Conglomerate) does not lie quite at the base of the Permo-Carboniferous rocks as developed in Western Australia. The Lyons Conglomerate marks an important geological horizon, which has been proved to extend for a distance of about 200 miles.

There are sound geological reasons for believing the Lyons Conglomerate to have been contemporaneous in age with those beds which afford evidence of the glaciation that affected India, South Africa, South America, and Eastern Australia.

The Permo-Carboniferous rocks of Western Australia have yielded a rich assemblage of fossils, which will be found set out at length in Geological Survey Bulletin 50 (*q.v.*)

The Western Australian Permo-Carboniferous fauna very closely resembles that of India.

According to recent researches into the palæontology of the Salt Range beds of India, it appears that *Spiriferina lata*, McCoy, of Western Australia, is hardly to be distinguished from *Spiriferina infer*, Wagg, occurring in the Lower *Productus* Limestone. *Spiri-*

fera Hardmani is merely a variety of *Spirifera Marcoui* occurring at Amb.; *Athyris Macleayana* is identical with *Athyris capillata*; *Aulosteges Baracoodensis* likewise can hardly be distinguished from *Aulosteges Medlicottianus*; *Productus tenuistriatus*, var. *Foordi*, Eth., from the group *Productus tumidus*. The fossils from the Irwin River beds also show an intimate relationship with those of the Productus Limestone of the Salt Range, viz.:—*Productus subquadratus* belongs to the series of *Productus Abichi*; *Productus undatus* is like *Productus opunta*, and *Productus tenuistriatus* resembles *Productus tumidus*.

JURASSIC.—The Jurassic rocks of the State have a fairly wide extent, especially in the Champion Bay district, near Geraldton. Rocks of this age have also been recorded from Sharks Bay and also from Cape Riche to the east of Albany. From this latter locality *Ammonites (Perisphinctes) Championensis*, sp. nov., has been recorded, but there is some doubt as to whether or not this specimen has been correctly localised, for it really may have come from Champion Bay. The Champion Bay beds cover a fairly large area of country to the south, in the neighbourhood of the coast line. They are seen to rest with a marked unconformity on the Carboniferous rocks of the Irwin River valley. They also extend northward, having been met with at Sharks Bay on the Gascoyne River, near the Kennedy Range. The Jurassic beds of the State are represented by oolitic limestones, clays, sandstones (which are often ferruginous), grits, conglomerates, and lignites. Some of the ferruginous sandstones contain abundant plant remains. As a rule the strata are horizontal or but gently undulating, and have probably been deposited along the then coast during a long period of depression. No estimate can as yet be made of the thickness of the Jurassic beds; they have, however, been pierced by four bore-holes in the Champion Bay district, which have proved the thickness to be not less than 2,000ft. The plant remains occurring in these beds near Mingenew seem to indicate that the beds are the equivalents of those at Talgai and Rosewood, in Queensland.

These Jurassic beds are of considerable economic importance, from the point of view of the occurrence of artesian water, and several abortive efforts have been made to reach them by means of deep bores beneath the Cretaceous rocks of the Metropolitan Area. The importance of these Jurassic rocks from the hydro-geological standpoint is their general permeability, which lends itself to the absorption and transmission of large quantities of water, whilst the thickness of the formation gives it a very large storage capacity.

A complete list of the Jurassic fossils will be found in Bulletin 50.

CRETACEOUS.—The presence of Cretaceous strata in Western Australia appears to have been known for pretty well half a century, having been first recorded by Mr. F. T. Gregory as occurring

near Gingin. This same observer stated that the Cretaceous strata were the most extensively developed of the sedimentary rocks of Western Australia, and that the beds were very closely connected with the Jurassic rocks of the Greenough River. The boundary between the two series, however, has not yet been satisfactorily traced.

Fossiliferous Cretaceous rocks have been proved in three districts, viz., Eucla, the Metropolitan Area, and Gingin, and there are good grounds for believing that beds of this age occur in the valleys of the Gascoyne, Lyndon, and the Minilya Rivers.

The results of the recent boring in that enormous limestone plateau which extends from the South Australian border to the neighbourhood of Israelite Bay has proved the occurrence of Cretaceous strata lying beneath the Eucla limestone, which is supposed to be of Eocene Age. In bore No. 3, put down at the 337 miles 61 chains peg on the surveyed route of the Western Union Railway, at an altitude of 576ft. above sea-level, the following strata were passed through:—Eucla limestone, 603ft.; shales (sometimes glauconitic), 667ft.; fine and coarse sandstone and conglomerate, 74ft.; and granite, 28ft.; the total depth of the bore being 1,372ft. The beds beneath the limestone have yielded two of the most characteristic fossils found in the Lower Cretaceous strata of South Australia and Queensland, viz., *Aucella Hughendensis*, Eth.; and *MacCoyella Corbiensis*, Moore, together with portions of a bivalve shell, possibly *Fissilunula*, which is found in the Lower Cretaceous beds of Eastern Australia. There is, therefore, little doubt that the strata pierced in No. 3 bore are the equivalents of the Rolling Downs Beds of Queensland.

The Cretaceous rocks of Gingin consist of white chalky limestone without flints, which passes downwards into a greenish glauconite marl, and below that into a clay shale. Above the limestone is a bed of very ferruginous sandstone, the whole series dipping to the northward at an angle of 8deg. to 9deg.

The Gingin beds have yielded an extensive series of fossils, and although the number of species which can be identified is comparatively small, nevertheless it contains much that is important and indicates that a large and important fauna could be obtained. Amongst the fossils (which will be found described in Geological Survey Bulletin 55) are new species of *Peronella*, *Coelosmia*, and *Pollicipes*, in addition to seven new species of Brachiopods and a new Gastropod. An important feature is the appearance in the Gingin beds of types new to the Australian Cretaceous rocks, though common in the beds of the old world, the Australian facies, however, being maintained by the presence of *Inoceramus* and *Ammonites*.

A purely homotaxial, though not a synchronal relationship, has already been shown to exist between the Cretaceous rocks of Australia and Europe, whilst as a result of recent palaeontological research into the rocks of Western Australia, it now appears that a

much nearer connection probably exists with the Cretaceous rocks of India, thus affording another instance of that close geological kinship existing between the countries bordering the Indian Ocean.

Further northwards, in the neighbourhood of Dandarragan, is a white chalky limestone, at the base of which lies a phosphatised bone bed, associated with sandstones and shales, which are occasionally glauconitic; these beds, which contain *Ostrea* and *Inoceramus*, are of the same geological age as the Gingin strata, with which they appear to be coterminous.

According to such geological field evidence as is at present available, the Cretaceous and Jurassic beds of the Coastal Plain owe their present position to faults, which trend generally north and south.

TERTIARY.—Owing to the absence of valuable mineral deposits the Tertiary strata have not as yet received much attention at the hands of the Survey.

The basal beds of what are believed to be Tertiary strata are seen to rest unconformably on the eroded surface of the Jurassic beds of the Champion Bay district. The beds consist of limestones, sandy shales, and sandstones, which form a relatively narrow strip of country along the coastline.

Similar strata occur at Sharks Bay and to the southward of Perth, extending as far as the South Australian border, where the chalky limestone that bulks largely in the formation contains fossils which seem to point to its being of the Eocene age.

In the South-Western portion of the State the Tertiary strata are associated with basaltic lavas as well as basaltic dykes. These basaltic lavas may be seen at Bunbury, at several places in the Blackwood River, at Black Point on the south coast, and near Silver Mount between the Warren and Donnelly Rivers. They were also cut in two of the bores put down in the search for petroleum on the Warren River.

In the Kimberley Division basic lavas and ashes occur in great force. These Tertiary lavas and ashes appear in the valleys of the Ord and the Bow Rivers to have levelled up the depressions formed therein, except certain knife-edged ridges of the older rocks which still protrude above the general level. On the Behn River, just above what is known as the Gorge, a dome or puy of basalt which apparently formed one of the foci from which some of these lavas issued, has been described.

At Norseman remnants of an extensive dolomitic limestone formation at an altitude of 900ft. above sea-level and 100 miles distant from the coast have been discovered. This bed at Norseman contains species of *Turitella*, allied to *T. terebra*, *Pecten*, *Cardium* (or *Cardita*), *Magellania*, and fragments of *Polyzoa*.

LATERITE.—No account of the geology of Western Australia would be complete without some reference to that extensive develop-

ment of residual deposits which occur in nearly all portions of the State, and for which the term laterite has been adopted. The laterites consist largely of hydrated oxide of iron and alumina, producing on the one hand deposits of iron ore, and on the other bauxite. In some localities the deposition of secondary silica in the laterite deposits produces what are practically quartzites. These, by an increase in the ferruginous colouring matter, pass into a jasperoid form of laterite. There are thus three forms of laterite: an aluminous, a ferruginous, and a siliceous, the composition being liable to vary considerably over a small area, it being governed largely by the nature of the underlying rocks. The laterites pass gradually into the underlying rocks without any sharp line of demarcation. The ferruginous and siliceous laterites are much commoner than the aluminous variety. This arises from the fact that the former types are better able to resist disintegrating influences; they thus not only remain themselves, but act as a protecting cover for the rocks beneath. The lateritic deposits occur as disconnected outliers which once formed part of a continuous deposit. It is difficult to escape the conviction that the laterites are of some geological antiquity, of which possibly the thickness and state of consolidation may be some measure. On such geological evidence as is available the laterites seem to be of earlier age than Late Tertiary, though there is but little doubt that similar deposits are forming at the present time in the State.

ECONOMIC GEOLOGY.

The principal mineral products of greatest importance in Western Australia, arranged in order of value, are gold, copper, coal, tin, lead, and phosphates. The metals and metalliferous minerals make up by far the greater proportion of the value of the output, being over 98 per cent. of the total. Over 54 per cent. of the total gold output of the State has been obtained from the East Coolgardie Goldfield, which contains the important mining centre of Kalgoorlie.

The mineral deposits of the State occur in areas generally as more or less parallel belts of relatively narrow lateral dimensions, though in certain localities they appear as small isolated areas or patches. These narrow well-defined belts have a general north-west and south-east direction, with occasional divergences of several degrees on either side. The ore deposits in these zones or belts, owing to dynamo-metamorphic processes, do not crop out in long lines, but are cut up into relatively short lenticles, arranged *en echelon*.

In addition to the minerals alluded to above, the State possesses a possible asset of very great value in the deposits of laterite which occupy such extensive areas in many localities. Some of the deposits contain considerable quantities of alumina, and are in every



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GEOLOGICAL SKETCH MAP OF WESTERN AUSTRALIA

Scale in Miles
0 10 20 30 40 50 60 70 80 90 100

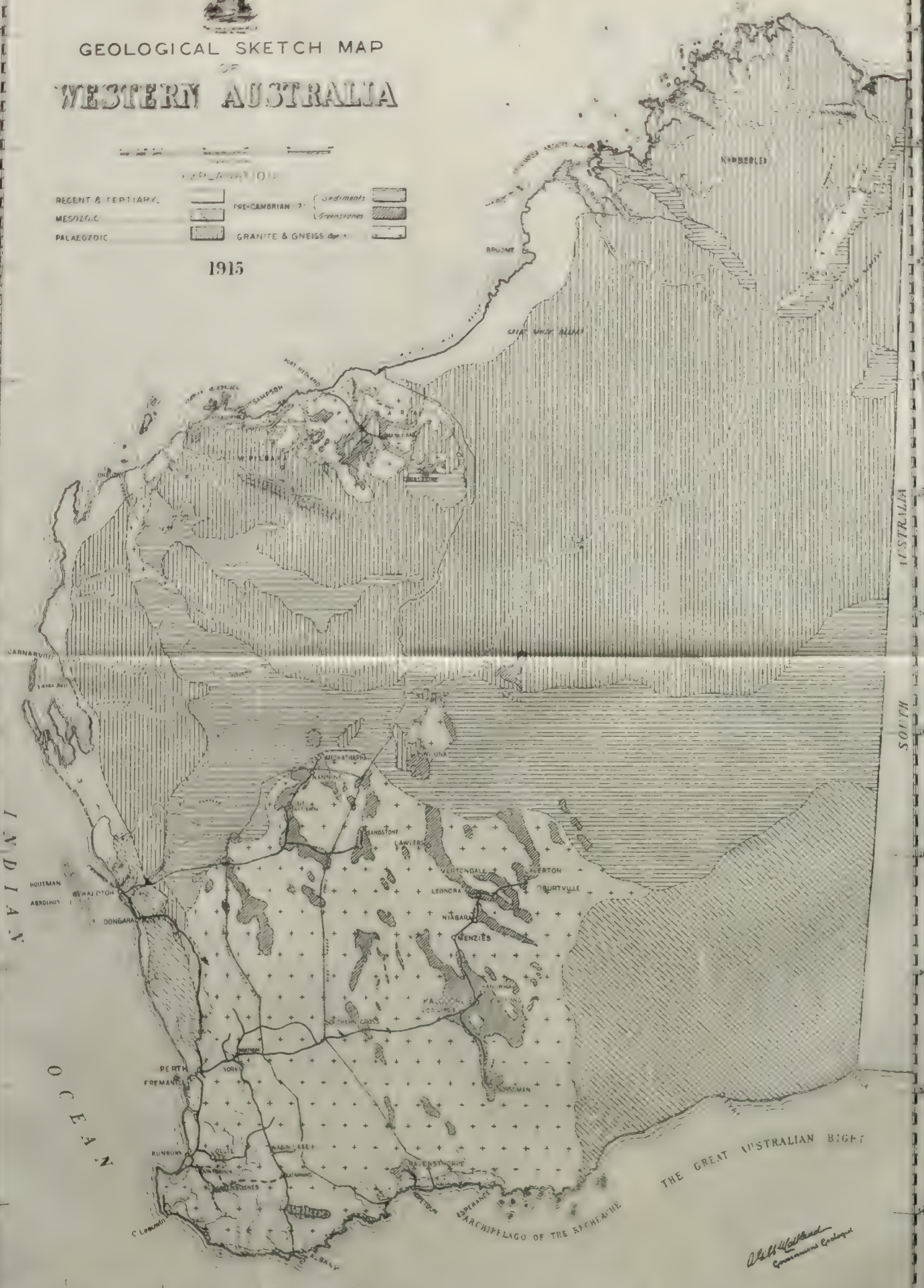
RECENT & TERTIARY.		PRE-CAMBRIAN {	Sediments	
MESOLIC.			Greenstones	
PALAEOZOIC			Granite & Gneiss	

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John Forrest
Commissioner of Geology

respect identical with bauxite, which mineral is now the chief source of aluminium.

Full details as to the geology of the mineral deposits will be found in Geological Survey Bulletin 50, and Chapter X. (The Mining Fields of Australia) of the Volume issued by the Commonwealth Government, and need not be repeated. (*Vide* No. 59, *postea*.)

REFERENCES.

Recent Advances in the Knowledge of the Geology of Western Australia. **A. Gibb Maitland**, Geol. Surv. Bull. 26, pp. 37-66.

Origin, History, and Work of the Geological Survey of Western Australia. **A. Gibb Maitland**, Ann. Rep. Geol. Surv., 1910.

The Geology and Mineral Industry of Western Australia. **A. Gibb Maitland** and **A. Montgomery**, Geol. Surv. Bull. 50.

Relics of the Carboniferous Ice Age in Western Australia. **A. Gibb Maitland**, Nat. Hist. and Sci. Socy., W.A., Vol. IV.

The Rare Metals and their Distribution in Western Australia. **E. S. Simpson**, Geol. Surv. Bull. 59.

Census of the Minerals of Western Australia. **E. S. Simpson**, Guide W.A. Museum and Art Gallery, Pt. VI., 1912.

A List of Western Australian Fossils systematically arranged. **L. Glauert**, Geol. Surv. Bull. 36, pp. 71-114.

The Mining Fields of Australia—Western Australia. **A. Gibb Maitland**, Commonwealth Handbook, Chap. X.

An Outline of the Physiographical Geology of Western Australia. **J. T. Jutson**, Geol. Surv. Bull. 61.

Geological and Physiographical Notes on a Traverse over portions of the Darling Plateau. **J. T. Jutson**, Geol. Surv. Bull. 48, pp. 138-173.

59.—THE MINING FIELDS OF WESTERN AUSTRALIA.*

By A. GIBB MAITLAND.

With a Map and Diagrams (Plates X., XI., XII., XIII., XIV.).

CONTENTS.

	PAGE
Introduction	92
Goldfields	94
Kimberley Goldfield	94
Pilbara Goldfield	94
West Pilbara Goldfield	97
Ashburton and Gascoyne Goldfields	97
Peak Hill, Murchison, Yalgoo, and Yilgarn Goldfields	98
The Eastern Goldfields	100
Copper Fields	103
Tinfields	104
Coal Fields	104

INTRODUCTION.

The State of Western Australia occupies the western third of the continent, and is estimated to embrace an area of 975,920 square miles.

The inception of active mining operations in Australia dates from the year 1842, when lead and copper lodes were first discovered and worked at Waneranooka, in the Northampton district of Western Australia. Since then the State has produced mineral products the total value of which, up to the end of 1912, amounts to £113,660,065; of this 54.5 per cent. has been obtained from the East Coolgardie Goldfield, which contains the important gold-mining centre of Kalgoorlie. The real mining history, however, dates from the year 1893.

The mineral fields are numerous and scattered over a very wide area. The total area of the proclaimed mineral fields amounts to 329,828 square miles; the position of these, as legally defined by the authorities, has been shown on the map of Western Australia included in the Report of the Department of Mines for the year 1912, and in Plate XIV. The legal boundaries of the mineral fields, however, bear no relation whatever to the geological boundaries.

The principal mineral products of greatest importance in Western Australia, arranged in order of value, at the end of 1912, are

* Written for the Australian visit of the British Association for the Advancement of Science, 1914.

gold, copper, coal, tin, lead, and phosphates. The metals and metaliferous minerals make up by far the greater proportion of the value of the output, being over 98 per cent. of the total.

The south-western corner of the State from Israelite Bay to Cape Leeuwin, and as far north as latitude 25deg. south, is a more or less broken tableland from which rise isolated hills and ridges of metamorphic and crystalline rocks to which a pre-Cambrian age has been assigned. This plateau forms the chief mineral region of the State. Isolated patches of variable extent of these older pre-Cambrian rocks rise from beneath the newer strata in the North-West and Kimberley divisions, and are as important from the mineral standpoint as in the south-western plateau.

The pre-Cambrian rocks are remarkable for the variety of useful and valuable minerals they contain, numbering up to date no less than 196.

There are sound reasons for knowing that the major portion of this pre-Cambrian plateau has been a land surface since early Palæozoic times, and having had such a peaceful geological history,* there has not been very much opportunity for mineralisation, hence the valuable ores have a very wide distribution instead of, with certain notable exceptions, being concentrated into very rich deposits. Whilst this is so, the results obtained by geological exploration, prospecting, and mining operations indicate quite clearly that the mineral industry of the State will not only be progressive but great. The future of gold mining in Western Australia, however, must in a great measure depend upon the exploitation of its low-grade deposits, of which there are very many.

Geologically the pre-Cambrian plateau is characterised by a more or less complicated structure. The plateau forms one general geological province in which the nature and mode of occurrence of the mineral deposits are more or less identical throughout. The interdependence of the mineral belts on the geological structure is exceptionally well marked in all parts of the State. The rocks are of very different types; many of them are in a crystalline condition and form coarse crystalline schists and gneiss as well as basic rocks, which have been more or less crushed, foliated, and completely converted into greenstone schists. The basic rocks comprise gabbro, dolerite, porphyrite, epidiorite, pyroxenite; in some localities these basic rocks can be seen passing by scarcely perceptible gradations into hornblende schists and allied rocks. Some of these older rocks are of sedimentary origin and are practically unaltered; others are quartz and mica schists, and in certain localities are cleaved conglomerates, some of the pebbles in which consist of a pre-existing conglomerate from a very much older series. The less altered members of these ancient sediments consist of a great variety of types

* For a general account of the Geology of the State, *vide* No. 58 *ante*.

of indurated slates, quartzites, and conglomerates, together with igneous rocks, which probably represent lavas and ashes.

These older rocks are invaded by batholiths and veins of granite and allied rocks, which in many parts of the State occupy very large areas. The old granitic rocks are traversed by many large ice-like quartz reefs, which rise like walls to considerable altitudes above the surface. The mode of occurrence, etc., of these large quartz masses point to their being of igneous origin, representing the final product of the differentiation of a granite magma, its ultra-acid portion. These older granitic rocks are of considerable importance by reason of the fact that they form the matrices of the tin and allied deposits of the State.

The mineral deposits of Western Australia occur in areas generally as more or less parallel belts of relatively narrow lateral dimensions, though in certain localities they appear as small isolated areas or patches. These narrow well-defined belts have a general north-west and south-west direction, with occasional divergencies of several degrees on either side. The ore deposits in these belts or zones, owing to dynamo-metamorphic processes, do not crop out in long lines, but are cut up into relatively short lenticles, arranged *en echelon*.

There are in all 24 proclaimed mineral fields in the State, though there are in addition other areas which have been proved to be mineral bearing, but which have not as yet been brought within the limits of any legally defined mineral field. Most of the mineral fields of Western Australia produce other metals besides gold, though in nearly all cases that is by far the most important product. (Plate X.).

Goldfields.

KIMBERLEY GOLDFIELD.—This, the most northerly goldfield in the State, discovered in 1882, is of historical importance, though it has not been a very notable gold producer.

The gold belt of Kimberley, a succession of crystalline schists of remarkable persistence, has been proved to extend from Denham River to Mount Dockrell, also in the Mueller Range, from whence it strikes north-westward along the foot of the King Leopold Range to King Sound.

This belt of rocks, micaceous and talcose schists, gneiss, and granite, varies in width from 10 to 30 miles, and has been shown to have a horizontal extent of at least 120 miles.

Mining and prospecting operations have been confined, however, to only six more or less isolated centres. These up to the end of 1912 have only produced 17,012.75 ozs. of fine gold.

PILBARA GOLDFIELD.—The Pilbara Goldfield contains several gold and tin-bearing areas, scattered over different portions of the

district; economically, however, the auriferous deposits have proved up to the present to be the most important.

The geographical position of the various gold-mining centres shows a zonal development of the auriferous deposits which may be divided into six main and distinct groups, viz.:—

- (a) Lalla Rookh;
- (b) North Pole, Talga Talga, Bamboo;
- (c) Marble Bar, Warrawoona, Yandicoogina, Mount Elsie, Boodalyerri;
- (d) Nullagine, 20-Mile Sandy, Mosquito Creek;
- (e) Tambourah, Western Shaw; and
- (f) North Shaw.

The length of the Lalla Rookh Belt has not yet been defined, but it does not appear to be less than 30 or 40 miles. The North Pole, Talga Talga, and Bamboo Belt is 50 miles in length. The Marble Bar, Warrawoona, Yandicoogina, Mount Elsie and Boodalyerri Belt has a proved extent of about 80 miles. The Nullagine, Middle, and Sandy Creek zone is known to extend for a distance of at least 40 miles, and there are strong geological reasons for the belief that it continues much farther to the east and may possibly cross the upper reaches of the Oakover River. The Tambourah and Western Shaw Belt has not as yet been accurately defined, but it does not appear to be less than about 30 miles in length, whilst that of the North Shaw has only been proved to extend for a few miles.

The general direction of these auriferous belts almost everywhere coincides with the strike of the schists which, with one or two exceptions, invariably form the matrices of the gold-bearing reefs. The prevailing dip of the belts coincides with the general trend of the main structural features of the district. Their width naturally varies, and in the three most northerly zones the width cannot be defined owing to the fact that one of the boundaries is invariably marked by a powerful fault, which throws down the newer beds against the schists.

Quartz reefs occur in great abundance all through the schistose rocks, as well as to a more limited extent in the areas occupied by the granitic rocks. The quartz reefs are of two distinct types, viz., white quartz reefs and laminated quartz and jasper veins approaching very closely the hematite-bearing quartzites (?) which invariably form a conspicuous feature in most of the goldfields of the State. Some of the laminated quartz veins range from almost pure quartz, through banded jaspers, with crystals of magnetite, to bands appearing to the eye to be virtually pure hematite. The quartz reefs, of what may be called the massive types, occur plentifully in both the schists and the granites. They invariably occur along the planes of foliation (? bedding) of the schists, or, at any rate, cut them at a low angle.

The auriferous reefs cannot be said to be long, and are, as a rule, small, though they occasionally swell out into large lenticular masses. Some of the reefs have been traced along the outcrop for over 2,000 feet, and have swelled out to masses measuring about 15 feet across.

In addition to the gold derived from quartz reefs, the conglomerates at the base of the Nullagine Series have been mined in two localities—Nullagine and Just-in-Time. It is noteworthy that the base of the series has only proved auriferous in those places where it lies upon that portion of the underlying formation which carries auriferous quartz reefs.

At Nullagine the auriferous strata occur through a thickness of about 300 feet of grits, sandstones, and conglomerates, which form the lowest portion of the series. The auriferous conglomerate is of sedimentary origin, and is made up of rounded and subangular fragments of the underlying strata. The portions of the strata which have proved to be gold bearing are those which are largely impregnated with the oxides and sulphides of iron, and which lie between a well-marked fault and a greenstone dyke. Mining operations have, up to the present time, been confined exclusively to the oxidised zone of the conglomerate and to very limited and shallow depths. The available evidence regarding the origin of the gold seems to indicate that it is a secondary and not an original constituent of the conglomerate; and owed its introduction to the percolation of mineral-bearing solutions down the most porous portions of the conglomerate, this condition being facilitated by the downward inclination of the bedrock, and possibly accentuated in part by the folding which the strata have undergone. Numerous dryblowers have been at work for a number of years over that portion of the conglomerate from which the crushings have been obtained, and have acquired a considerable quantity of gold, of which the published figures afford no clue. In all probability one-half of the "alluvial" gold from Nullagine may be legitimately claimed to have been derived from the escarpment of the conglomerate.

At Just-in-Time, 8 miles to the south of Marble Bar, another auriferous conglomerate at the base of the series has been worked. In many respects the auriferous conglomerate resembles the ferruginous bands as developed at Nullagine, and varies in thickness from an inch up to 5 feet. Certain portions of it contain a sufficient quantity of iron oxides to give quite a distinctive character to the rock. The auriferous conglomerate of Just-in-Time is, however, not of any very great horizontal extent, nor does it appear to penetrate to any considerable depth. As has been the case at Nullagine, the sloping ground at the foot of the escarpment has yielded considerable quantities of gold to the dryblowers, but, unfortunately, it did not appear to have been possible to keep a separate record thereof. Most of the gold obtained in this way owed its origin to the disintegration of the conglomerate.

The Pilbara Goldfield has, up to the close of 1912, produced 166,914.21 ozs. of fine gold, of which 3,264.59 ozs. have been obtained from the conglomerate.

WEST PILBARA GOLDFIELD.—The West Pilbara Goldfield is of some historical interest in that it contains one of the oldest mining centres in the State. The mining history of the field opened with the discovery of rich copper and lead deposits in the vicinity of Roebourne during the year 1872, though it was not until five years later that auriferous quartz reefs were reported and opened out. Since then West Pilbara has turned out 54,172.84 tons of copper ore and 22,601.98 ozs. of fine gold in addition to small quantities of tin and iron ore. The area of the West Pilbara Field, as legally defined by the authorities, embraces 9,480 square miles, of which, however, only about 1,500 are occupied by mineral-bearing formations, for by far the largest portion of the field is covered with the andesites, dolerites, conglomerates, quartzites, and shales of the Nullagine Series, which effectually conceal the older rocks beneath. The remaining portions of the field consist of granite and gneiss, together with a series of metamorphic rocks of both sedimentary and igneous origin, and a series of basic dykes of pre-Nullagine age. The valuable ore deposits of West Pilbara are confined to the northern and eastern portions of the field.

The most important gold-mining centre is Station Peak, situated on the head waters of the Peewah River. In its geological structure Station Peak is comparatively simple, consisting of a highly inclined series of sedimentary rocks invaded by basic and acidic dykes. The sediments are traversed by a dyke of quartz-dolerite, which varies from 800 to 1,000 feet in width; this dyke forms the most important economic feature in the geology of the field, owing to its forming the matrix of the reefs which up to the present time have proved to be auriferous. The gold-bearing quartz reefs of Station Peak have a more or less parallelism, which is roughly approximate to the general strike of the dolerite. The reefs vary in thickness from $\frac{1}{8}$ inch up to as much as 20 feet, whilst the maximum length attained by the most important is 4,000 feet. These reefs have yielded 9,382 ozs. of fine gold, from the milling of 9,993 tons of quartz. This yield forms nearly one-half of the total gold output of the West Pilbara Field.

Pre-Cambrian deposits of several types, containing copper, gold, antimony, etc., are found in several parts of the districts, associated with those bands of laminated quartzite which make such conspicuous features in the structural geology of the field.

Up to the end of 1912, the West Pilbara Field has produced 22,601.98 ozs. of fine gold.

ASHBURTON AND GASCOYNE GOLDFIELDS.—The Ashburton and Gascoyne Goldfields are situated on the headwaters of the Ashburton and Gascoyne Rivers respectively. They do not embrace any large

area, and have not so far been very noteworthy gold producers. There is a great diversity of geological formations, though in its broad outlines the geological features of the goldfields are fairly simple.

As is the case in West Pilbara, by far the larger known area is made up of representatives of the Nullagine Series, which constitute the high plateau breached by the Ashburton River. The two fields contain several minor gold-bearing areas, scattered over widely separated localities. The auriferous deposits are of diverse types, and possibly of different geological ages.

At Bangemall, on the Lyons River, in the Gascoyne Goldfield, the productive auriferous area lies between two beds of micaceous quartz schist, forming the legs of a denuded anticline, which has a decided pitch to the south-east. These two bands trend across country for considerable distances, and are associated with auriferous quartz veins. The most important feature, however, is the saddle-reef nature of the quartz veins, which bears a striking resemblance to those of Bendigo in Victoria.

There are some sound geological reasons for believing this auriferous belt to extend as far westward as Mount Egerton.

The gold-bearing zone of the Ashburton Valley is defined by the escarpment of the Nullagine Series which flank both walls thereof, and has been estimated at 10,000 square miles. There are five centres at which mining operations have at one time or another been carried on. The primary gold deposits are contained in a highly inclined series of sedimentary rocks, quartzites, grits, and slates, having an average strike of 122 degrees. The beds are in most cases traversed by quartz reefs of varying dimensions and interrupted continuity. The strata are disposed in a series of more or less acute folds, and the reefs, which occur on the flanks of the arches, may possibly represent the legs of saddle reefs now modified by denudation. The coarse gold obtained from many of the gullies doubtless owed its origin to the disintegration of the quartz reefs.

Up to the close of 1913 these two fields have produced 9,411.04 ozs. of fine gold.

PEAK HILL, MURCHISON, YALGOO, AND YILGARN GOLDFIELDS.—The dependence of the mineral-bearing zones on geological structure is exceptionally well marked in the three most westerly of what may be called the Central Goldfields. The important ore deposits are confined largely to a diagonal belt extending from Mount Beasley, on the north, to Mount Singleton, near the extremity of the westernmost arm of Lake Lefroy, on the south. The mines of the belt yield almost entirely gold, though there are a few localities from which small quantities of copper and tin have been obtained and are not so far of any great importance. The geological structure of the mineral zone is remarkable for its uniformity; it may be described as a series of more or less persistent zones of schists and allied metamorphic

(in parts sedimentary) rocks forming a distinct lithological province. The schists and their associated rocks are remarkable for their persistent strike and horizontal extent, one belt alone having been proved to extend for at least 60 miles. These zones of schists are everywhere surrounded by granite, which seems to be of two distinct geological ages, viz., an older, which has undergone the same dynamic alteration to which the schists owe their origin, and a much newer, which penetrates the older granite as well as the schists. The schists are associated with diabase (dolerite), pyroxene, and allied rocks, and there are sound reasons for believing that some at any rate of the schists merely represent crushed or plated out varieties of the basic rocks. Some of the basic rocks are traversed by belts of laminated quartzites intersected by numerous faults, which are of considerable economic importance by reason of the fact that it is along these fault lines that rich shoots of gold often occur.

The principal mining centre along this belt is Day Dawn, where one of the largest solid quartz reefs, the Great Fingall, mined anywhere is situated. This reef, which has an outcrop of about 30 chains in length, produced up to the end of 1912 1,080,415 ozs. of fine gold, and 150,470 ozs. of silver from the milling of 1,642,089 tons of ore. The outcrop, when first discovered, was of considerable size, and rose above the general level of the surface in a series of camel-backed ridges from 10 to 20 feet in height.

The average dip of the reef is about 60 degrees to the south-westward, and its maximum thickness 40 feet. The lowest vertical depth at which the reef has been mined is 2,342 feet. The Great Fingall lode is more or less transverse to the general trend of the "Auriferous Series," and occupies a relatively narrow belt of schistose amphibolite which is traversed by basaltic dolerite and porphyry dykes. The quartz below water level contains small quantities of pyrites, pyrrhotite, mispickel, zineblende, galena, and a little copper pyrites.

The mineral zone, which traverses the Murchison Goldfield, seems to be continuous southward through the Yilgarn Goldfield, of which the official centre is Southern Cross. The first authentic gold find on the Yilgarn Goldfield was made at Ernoon in 1887, this was shortly afterwards followed by the discovery of the pioneer mine, Fraser's, at Southern Cross, which has been continuously worked for over 25 years.

The Fraser's Lode occupies a belt of considerable length, and it outcrops at intervals in the form of lenses occurring in a shear zone of amphibolite and its derivatives. This shear zone contains more or less pyrites, and it has been found that the gold values bear an intimate relation to the extent of the mineralisation. The lode is intersected, in a direction at right angles to its general trend, by dykes of pegmatitic granite, and where this occurs there is a slight impoverishment of the lode at the points of contact.

The Yilgarn Goldfield has, since its discovery, produced 407,770 ozs. of fine gold, of which the Fraser's Lode alone yielded 172,471 ozs. of fine gold. These banded ferruginous quartz lodes when seen below the oxidised zone pass into schists with pyrites with thin seams of magnetite and pyrrhotite. The Mount Caudan Bore, put down in what is regarded as the southerly extension of the Fraser's lode ore channel, passed through 100 feet of massive pyrrhotite at a depth of 600 feet from the surface. The pyrrhotite, however, contained only a minute trace of gold.

The mineral zone, in which this persistent ore channel lies, is of considerable horizontal extent; it is really constituted of a series of very long belts arranged more or less *en échelon* and encased in basic rocks, some of which may be of sedimentary origin. The larger area of the field is of granite, which is of distinctly later origin than the greenstones, which are invaded by dykes of pegmatite and veins of granitic quartz.

The Yilgarn Goldfield has, since the inception of mining operations, produced 407,770 ozs. of fine gold.

THE EASTERN GOLDFIELDS.—There is a remarkable uniformity in the geological structure and mode of occurrence of the mineral deposits of the Eastern Goldfields. The auriferous districts are of interest on account of their wide distribution and regular mode of occurrence of the gold-bearing deposits.

Very large areas of the surface are covered with a variable thickness of recent accumulations, which have sometimes solidified into cement.

The staple formation, however, is granite, gneiss, and a series of schistose rocks, some of which are of sedimentary origin; associated with these are large areas of basic rocks of different types and possibly of different origins. As in other portions of the State, the general strike of the schists is north-west; they are very often vertical or at any rate inclined at high angles. Gold occurs generally at no great distance from granite intrusions and along shear zones or shatter belts containing quartz veins or quartz lenses. These zones or belts are often cut by pegmatites and porphyry dykes, which in places have been fractured and the resulting cracks filled with quartz. The acid dykes are often impregnated with iron pyrites which is occasionally auriferous. The schistose rocks are often associated with hematite-bearing quartzites, some of which might be concentrated into high-grade iron ores. The proportion of oxide of iron in these rocks varies from practically pure hematite to a pure quartz-rock, often permeated by secondary silica which has also penetrated the surrounding rocks. These banded quartzites are occasionally auriferous.

In the North-East Coolgardie Goldfield, considerable interest attaches to the alluvial leads, the most prominent of which is the North Lead at Kanowna. This lead lies in an old water-course

carved out of the older rocks, and has been proved to be not merely a simple isolated run of auriferous gravel, but part of a series of old stream deposits. The width of the North Lead varies from two to 80 feet, whilst the thickness of the deposit in the old channel varies from a few inches up to 90 feet. The fall of the lead is about 40 feet to the mile. The deposit consists of surface loam, underlaid by a gravelly ironstone, often partially cemented by kaolin and oxide of iron into solid rock; beneath this lies a bed or beds of practically pure kaolin ("pug") and a varying thickness of a pebbly quartz wash. The quartz wash is occasionally cemented by secondary silica into a hard compact quartzite. Most of the gold in the North Lead has been won from the quartz wash, although the overlying kaolin and ironstone gravel have also yielded fair quantities. The ultimate derivation of the gold in the North Lead is from the quartz veins and lodes (upon which the wash directly reposes in places) by which the fundamental rocks are traversed. The gold is not exclusively in the form of grains, scales, etc., etc., but is found occurring in the quartz pebbles themselves. In addition to the undoubtedly detrital gold, there is another massive, arborescent or coarsely crystalline form which occurs, filling certain irregular cracks and covering cleavage planes or shrinkage cracks so as to present the appearance of painted surfaces. The mode of occurrence, associations, and character of this gold all point to a secondary origin, and it is of importance to note that this secondary gold has been deposited from solution, not only in the alluvium and other superficial deposits, but also in the zone of decomposition of the bed-rock. These secondary forms of gold, which result in the superficial enrichment of many gold-bearing deposits, are a not uncommon feature in the mineral fields of the State.

The East Coolgardie Goldfield, the most productive in Australia, which has yielded £13,364,384 of gold, or about 55 per cent. of the total yield of the State, embraces an area of 632 square miles. The principal mining centre on the goldfield is Boulder, the wealth of which coupled with the skill which directs both the mining and metallurgical operations, has raised Western Australia to the front rank of gold-mining countries in the British Empire.

The productive area of Boulder comprises a relatively small block of ground, which by reason of the richness of the lodes by which it is riddled, has become known throughout the world as the "Golden Mile." This area includes the Great Boulder, Ivanhoe, Golden Horseshoe, Perseverance, Oroya-Brown Hill, Associated, and Lake View Consols Gold Mine. The deepest shaft is over 2,800 feet vertically below the surface, and the country laid open by mining for investigation amounts to several miles, whilst the rocks have been riddled with bore-holes in all directions, thus affording opportunities for the scientific study of many of the rocks in critical localities and in their relation to the ore deposits, such

as are hardly to be found in any other single mining field on the globe.

The rocks of Kalgoorlie and Boulder consist of:—(a) Ancient sedimentary rocks; (b) older greenstones (calc-schists and fine-grained amphibolites); (c) newer greenstones (quartz-diorite and coarse-grained amphibolite); (d) peridotites; (e) porphyrites; and (f) quartz and felspar-porphyrates.

The ancient sedimentary rocks consist of shales, soft sandstones, and conglomerates and boulder beds, associated with what appear to be inter-bedded lava flows. These sedimentary rocks have a general north-north-west trend, and an average dip of about 80 degrees to the west. They cover a very wide extent of country and have been found near Coolgardie in the west, and Kurnalpi on the east, whilst a similar series of metamorphic sediments have been found to the southward at Norseman on the Dundas Field, where they are intersected by a large number of quartz porphyry dykes which form the apophyses of the large granite mass lying to the east of the Norseman auriferous belt.

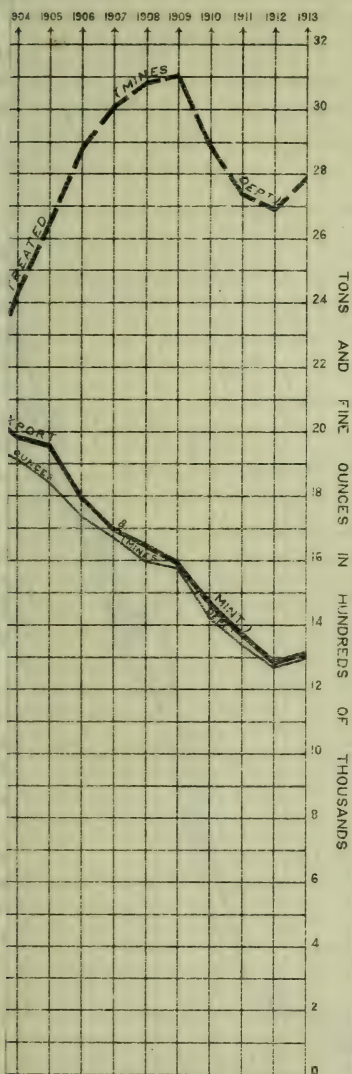
The sedimentary series of Kalgoorlie are traversed by banded jasperoid and hematite quartz, of that type which forms such a conspicuous feature in the geology of the sedimentary area of Uaroo, in the Ashburton watershed. There seems to be some reason for believing the Kalgoorlie sedimentary rocks to be divisible into two distinct series of different geological age, and distinctly newer than the complex which forms the axis of the Boulder auriferous belt.

Of the rocks of the Boulder-Kalgoorlie igneous complex, the quartz-diorite (dolerite) is the most important as it is within this and its alteration products that the principal gold-bearing deposits at present known occur. The quartz-diorite is, as a rule, massive, though owing to the dynamical and concomitant chemical alteration which it has undergone, the rock occasionally assumes a more or less schistose phase.

The principal effect of the chemical alteration has been the extreme carbonating which has gone on over certain portions of the mass, this being naturally greatest where the shearing of the rocks has been most pronounced. The diorite, owing to this chemical alteration, has been converted into an indefinite mixture of carbonates of lime, iron, and magnesia, with some residual silicates and a good deal of secondary and some original quartz. The carbonating is often of considerable extent and has been proved to be fairly deep seated, having been noticed at depths of over 2,000 feet.

The ore deposits of the field form relatively narrow bands, trending generally north-west and south-east. Many of the ore lenses are of great length, and in some cases of considerable breadth; at times, however, the lateral continuity of the lenses is

of the Royal Mint for each Year since 1886,
of Ore treated for each Year since 1897.



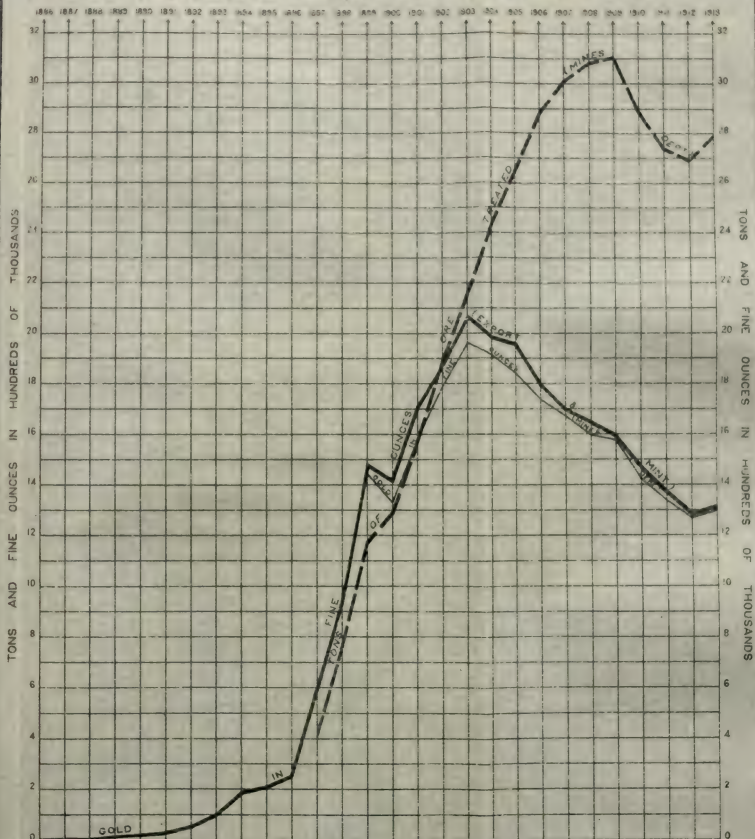
27,045,168 Fine ozs valued at £114,880,573, - Mines

reference of 1,230,743 Fine ozs. valued at £5,227,865.

F. Feldmann del.

GOLD DIAGRAM

Showing the Quantity of Gold entered for Export and received at the Perth Branch of the Royal Mint for each Year since 1886, with the corresponding Output referred to the Home Department and the Turnout of the treated for each Year since 1897.



Note: the quantity of Gold entered for Export and received at the Mint since 1886 totals 27,045,568 fine ozs. valued at £114,880,573; - Mines Dept. returns for the same period total 25,814,425 fine ozs. valued at £109,652,708, a difference of 1,231,143 fine ozs. valued at £5,227,865.

FR. Feldmann del.

interrupted by overthrust and normal faults of very variable downthrow. The principal lode minerals, in addition to gold and tellurides (calaverite, petzite, sylvanite, hessite, coloradoite, and altaite) are iron-pyrites, marcasite, chalcopyrite, tennantite, asbolite, carbonates (of iron, lime, and magnesia), sulphates (of lime and magnesia), iron ore (haematite, magnetite, ilmenite, etc.), tourmaline, chlorite, albite, rutile, etc. Next to the gold and tellurides, iron pyrites is the most important of the lode minerals; the grain or texture of the pyrites seems to bear some intimate relationship to the gold contents, and it has been noticed that the finer the grain the higher the gold values.

Copper Fields.

The known workable deposits of copper occurring in Western Australia are everywhere met with in areas which have been subject to violent earth movement and concomitant volcanic activity. They all show more or less similarity in their associations, mineralogical characters, and structural relations.

Copper mining, however, is not as yet a very important feature in the mineral production of the State, though the total output of copper ore up to the end of 1912 amounts to 185,935.08 tons (Plate XI.). Copper ores, however, are widely distributed throughout the length and breadth of the State, but owing to a variety of causes have been worked only in a very few districts. The principal sources of copper are West Pilbara, Mount Morgans, and the Phillips River; the largest output, 72,190 tons, being from Phillips River, 54,172 tons from West Pilbara, and 47,860 tons from Mount Morgans.

THE PHILLIPS RIVER FIELD consists of a series of metamorphic sedimentary rocks, associated with a complex series of crystalline rocks, which latter are of igneous origin, and range from granite to serpentine with their cleaved and schistose varieties. The lodes of the field, which have a uniform strike of east-north-east, are of two types; the first being basic cupriferous dykes, and the second siliceous or ferruginous deposits, of what may be called the shear-zone type.

THE MOUNT MALCOLM COPPER MINE at Eulaminna (late Anaconda) in the Mount Morgans district, has yielded nearly one-third of the copper production of the State. The whole of the copper-bearing belt is in basic rock, with quartz, jasper, and ironstone veins which show little or no copper at the surface. The ore has been concentrated into zones of enrichment, in reality bonanzas, three of which have been worked at the surface to comparatively shallow depths. Nothing very definite is known of the precise geological relationships of the Anaconda copper deposit.

THE WEST PILBARA GOLDFIELD has been a large producer of copper, which, however, has been obtained principally from one property, the Whim Well Copper Mine. This lode has proved to be the

largest and richest copper ore body yet discovered in Western Australia in the oxidised zone. The country rock in which the deposit is situated is a weathered talcose schist, associated with beds of a sedimentary origin. The ore deposit is a very flat-lying lode, conforming to the bedding of the enclosing schist country, which has a general strike of north-west and south-east.

Tin Fields.

There are only two districts in Western Australia in which tin mining has been carried on, viz., Greenbushes and Pilbara (Plate XII.). From the former locality 8,477 tons of tin ore have been raised, whilst the latter produced 4,886 tons; a small quantity, however, has been obtained from the Murchison Goldfield.

Wherever the tin deposits of Western Australia have been examined they are invariably found to fall into two distinct geological categories:—

1. Superficial deposits, which include (a) alluvial deposits; (b) residual sands, gravels, etc.; and
2. Deposits in country rock, which embrace (c) tin-bearing granite and allied rocks; and (d) tin-bearing dykes.

The alluvial deposits, which are the most important of any yet opened out in the State, vary very largely in nature and range from an extremely hard ferruginous conglomerate to a stiff clay or loose sand or gravel. The tin-stone in the first-named is often extremely coarse, whilst that in the softer material is almost uniformly fine.

In the Greenbushes field the alluvial deposits may be divided into two main groups, the older being the old river courses or deep leads, and the newer being represented by the existing channels.

In the latter the tin-bearing gravels often lie at from 10 to 40 feet from the present stream bottoms; the older deep leads attain considerable depths, the deepest being 96 feet.

The residual deposits are either lateritic ironstone or sands, clays, etc., derived from the decomposition *in situ*, of igneous rocks. Deposits of this type are frequently stanniferous, the chief minerals accompanying the tin are limonite, quartz, tourmaline, and mica.

Coal Fields.

The Collie Coal Field is the only one upon which any active operations are being carried on, though there are districts in the State in which lignites and brown coals occur.

The Collie Coal Field lies to the east of Bunbury and south of Perth, near the north-western edge of the tableland which succeeds the Coastal Plain. The area occupied by the coal measures is approximately 50 square miles. The strata consist of alternations of shales, sandstones, and grits of Permo-Carboniferous age, which rest directly upon granite, schists, and other crystalline rocks. The boundary of the field is, with one exception, everywhere defined by

TONS IN THOUSANDS, POUNDS STERLING IN TENS OF THOUSANDS

M

Sterling of Metal fo



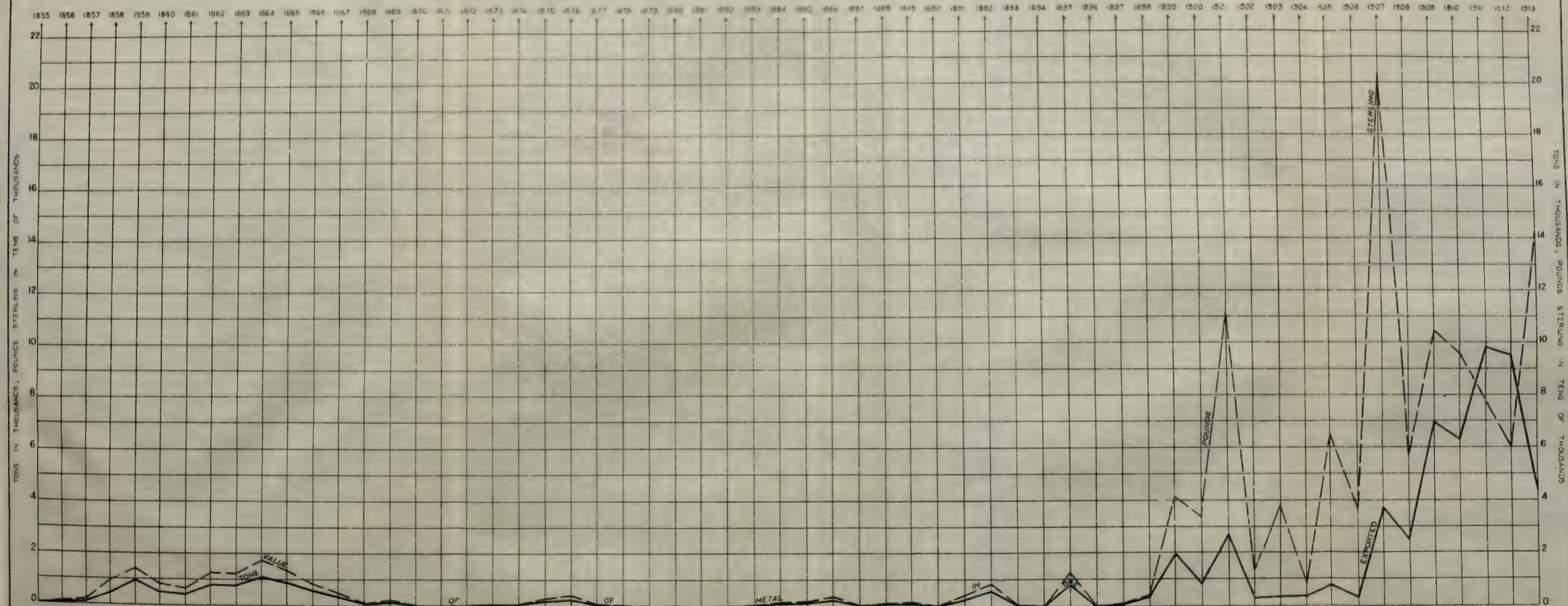
orted between 1900 and



U.S. Steel Corporation, Pittsburgh, Pa.

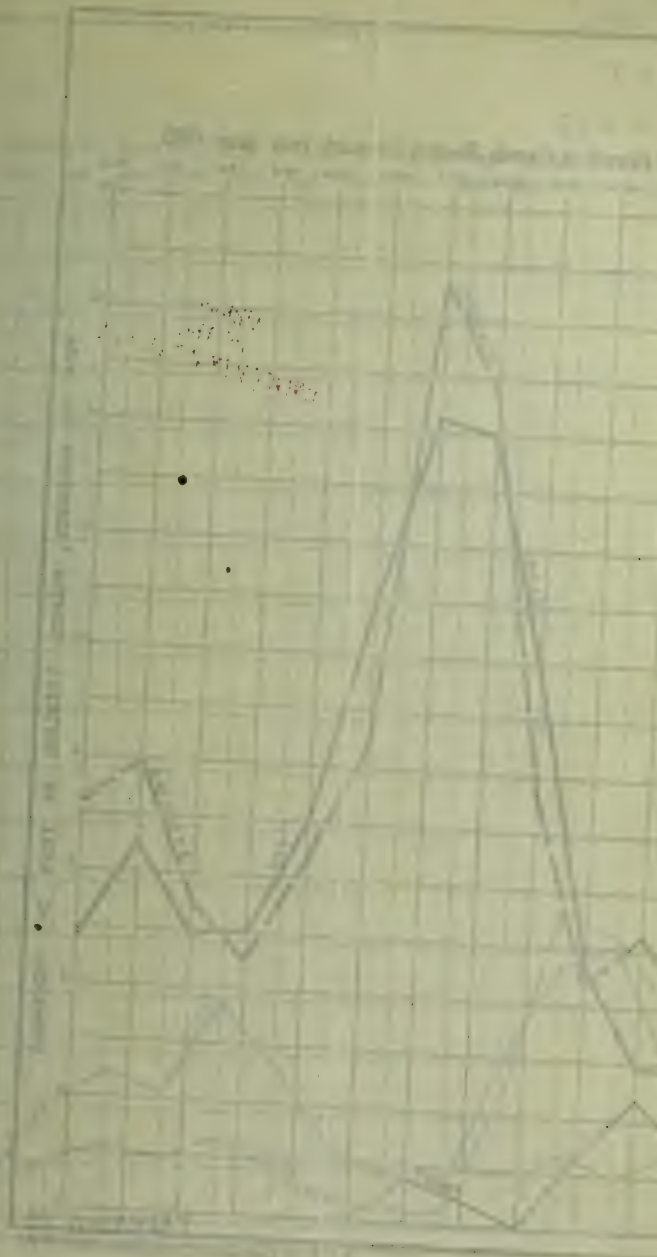
COPPER ORE VALUE DIAGRAM

Shewing the Quantity in Tons of Ore exported and the total Value in Pounds Sterling of Metal for each year since 1855.



Note: in addition to the above quantity of ore, 8751 tons of ingot, matte, etc., to the value of £537,503, were exported between 1900 and 1913; this value is included in the total value.

F.R. Feldmann del.



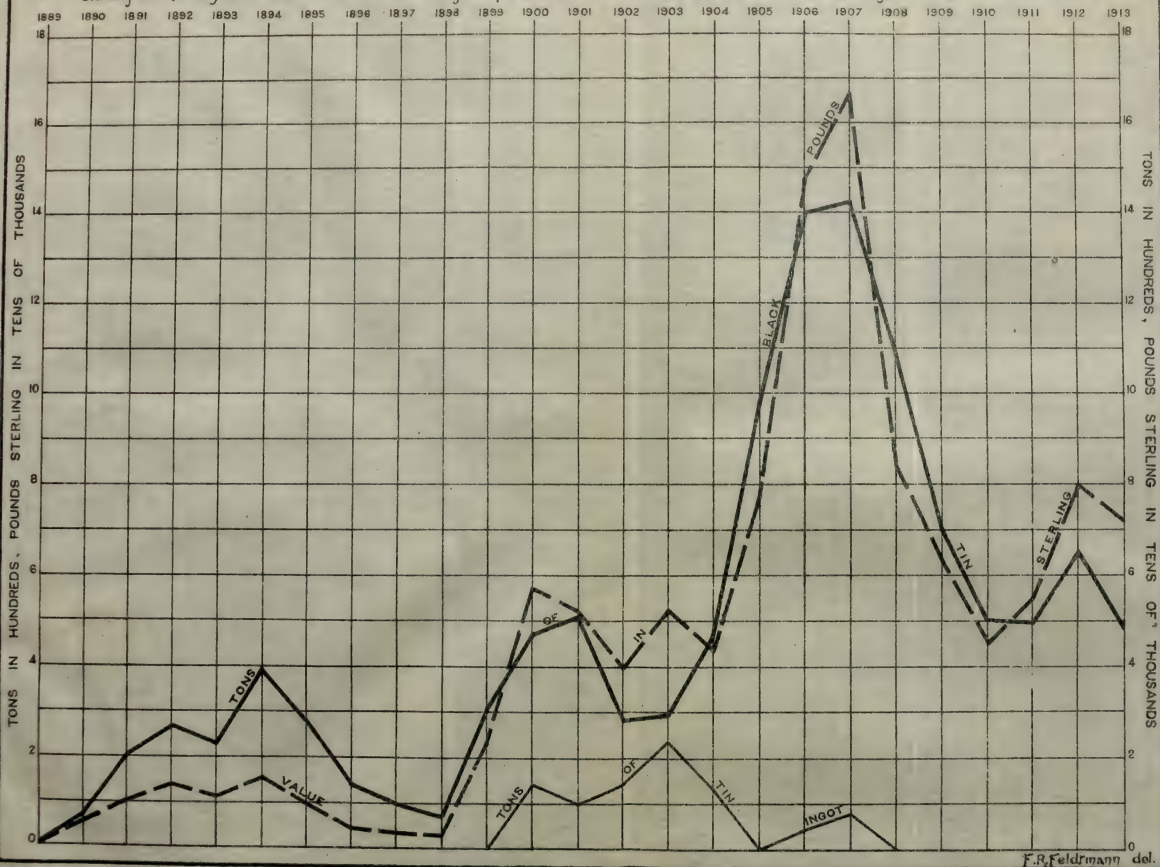


A. GIBB MAITLAND
GOVERNMENT GEOLOGIST

BULLETIN N° 64, PLATE XII.

TIN DIAGRAM

Showing the Quantity in Tons of Black Tin and Tin Ingot exported, and the total Value thereof in Pounds Sterling for each Year since 1889.



F. B. Feldmann del.

H. J. Pether, Government Lithographer, Perth, W. A.

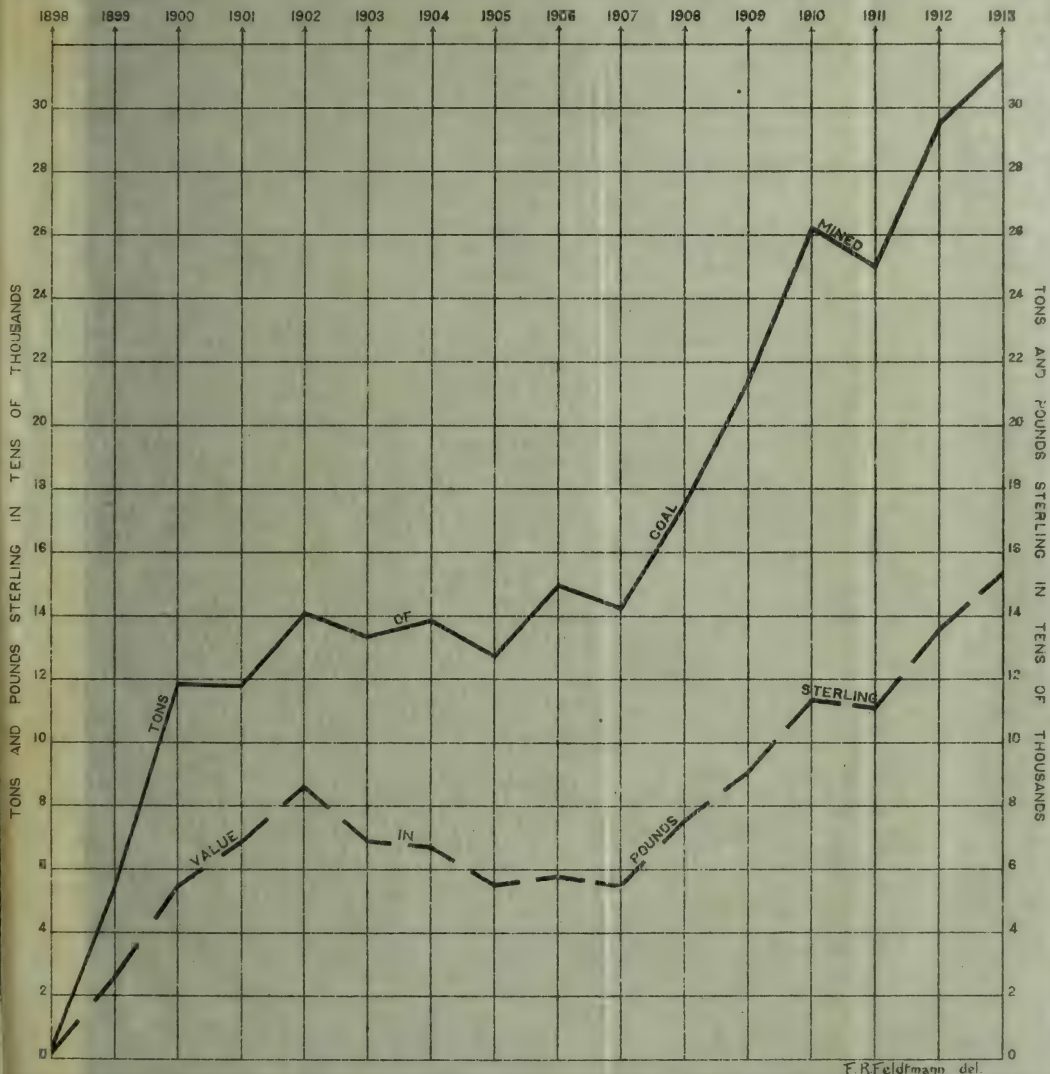


A GIBB MAITLAND
GOVERNMENT GEOLOGIST

BULLETIN No 64. PLATE XIII.

COAL DIAGRAM

Showing the Quantity in Tons of Coal mined and the Value thereof in Pounds Sterling for each Year since 1898.

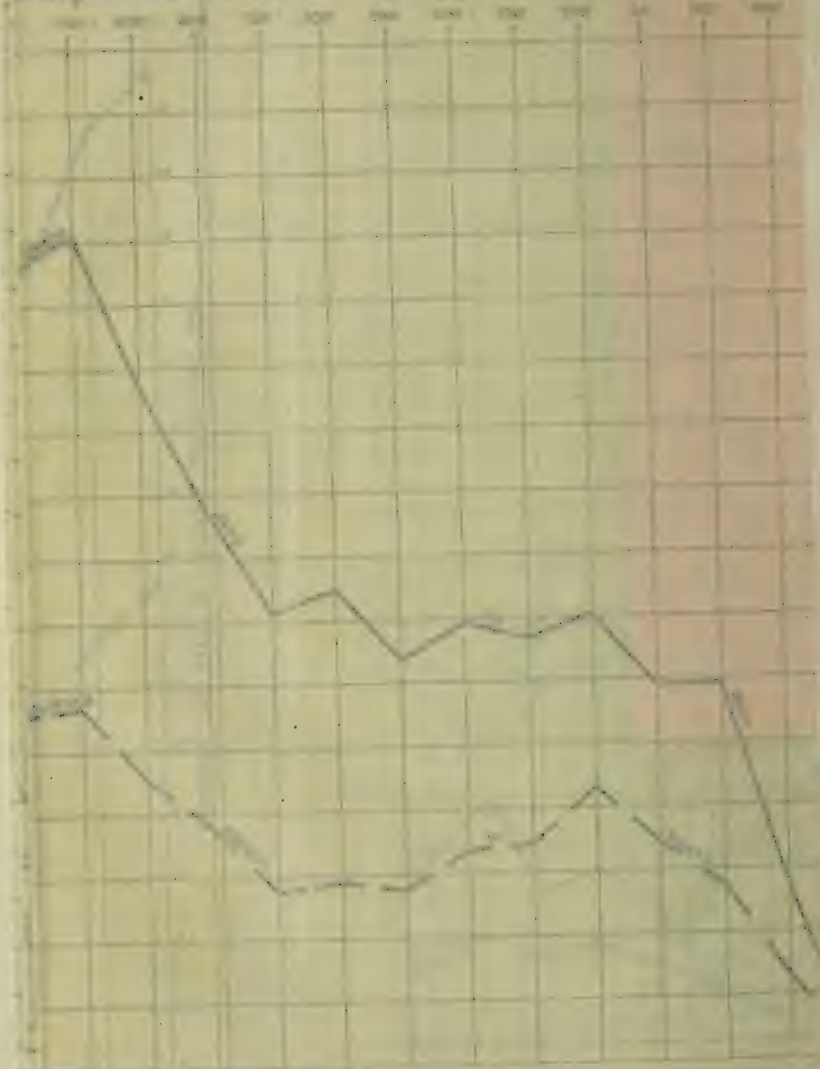


F. R. Feldmann del.

H. J. Pether, Government Lithographer, Perth, W. A.

COAL MARKET

The following is a list of the coal fields in the United States, showing the amount of coal produced in each field, and the total amount of coal produced in the United States.





112 STAFF 1918 100 100





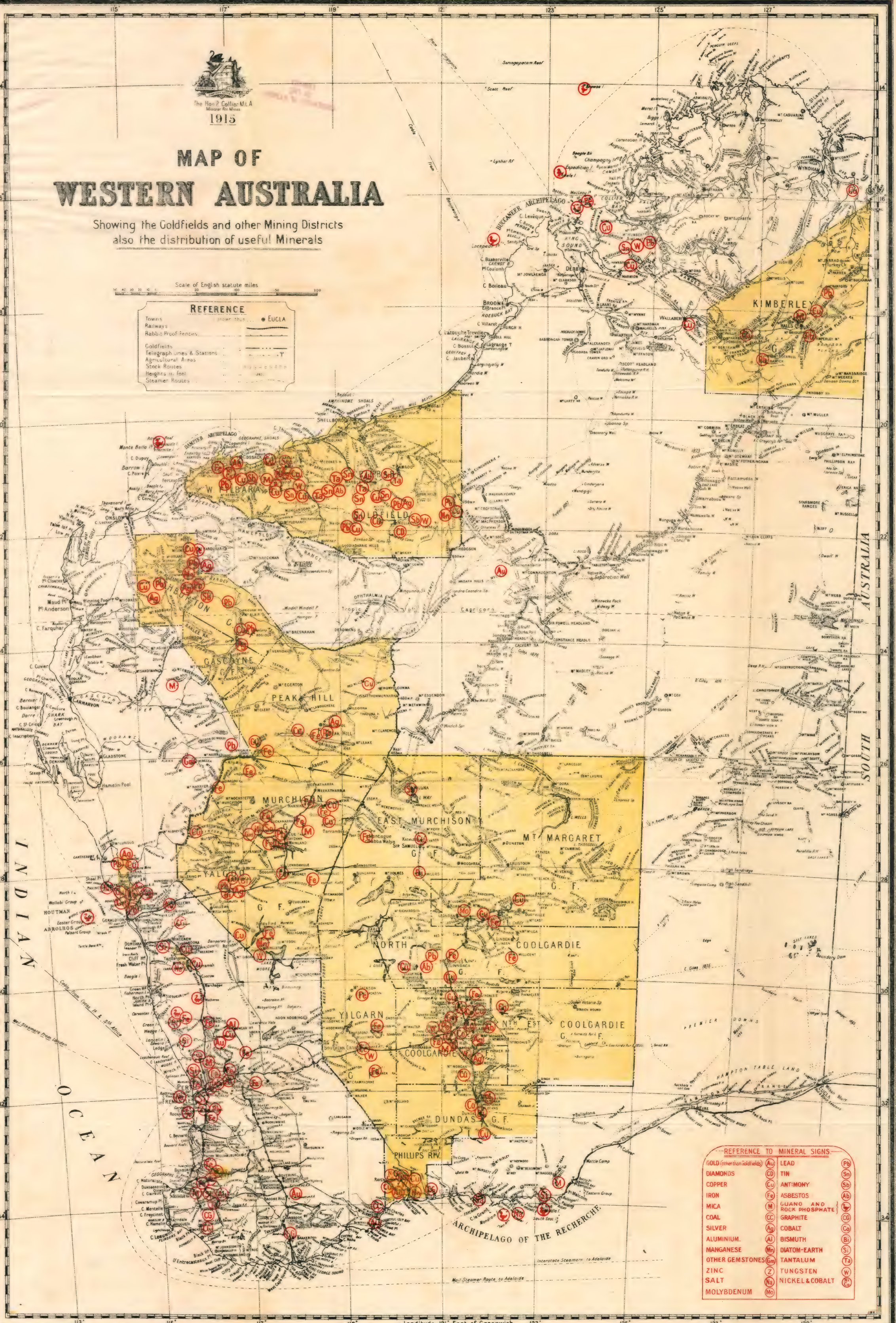
MAP OF WESTERN AUSTRALIA

Showing the Goldfields and other Mining Districts
also the distribution of useful Minerals

Scale of English statute miles

REFERENCE

Towns ● Eucla
Railways —
Rabbit Proof Fences ---
Goldfields ■
Telegraph lines & Stations ---
Agricultural Areas ---
Stock Routes ---
Heights in feet ---
Steamer Routes ---



—REFERENCE TO MINERAL SIGNS—

GOLD (other than Goldfields)	CU	LEAD	Pb
DIAMONDS	CD	TIN	Sn
COPPER	CU	ANTIMONY	Sb
IRON	Fe	ASBESTOS	Ab
MICA	M	GUANO AND ROCK PHOSPHATE	Gp
COAL	C	GRAPHITE	G
SILVER	Ag	COBALT	Co
ALUMINIUM	Al	BISMUTH	Bi
MANGANESE	Mn	DIATOM-EARTH	Di
OTHER GEMSTONES	Gm	TANTALUM	Ta
ZINC	Z	TUNGSTEN	W
SALT	Na	NICKEL & COBALT	Ni
MOLYBDENUM	Mo		

Longitude 121° East of Greenwich

faults; on the south-western side of the field the boundary fault has been estimated to have a downthrow to the north-east of at least 2,000 feet. There are several coal seams on the field, which are of variable thickness, the greatest being the Wallsend seam, which varies from 9 to 17 feet. According to estimates which have been made there is, omitting the seams of trifling thickness, about 137 feet of coal in the 2,072 feet of strata so far explored by mining and boring operations. The coal workings are very shallow, and, owing to the comparative freedom of the field from serious tectonic disturbances, difficulties which would otherwise be involved in working the seams are not encountered.

The coals of the Collie are hydrous semi-bituminous, non-caking coals, which approach very closely to lignite in some parts; between the various varieties, however, the differences are only of degree. So far as departmental analyses indicate, it appears that the average calorific value of the Collie coal is about 10,000 British thermal units. The coal is not of such high calorific value as the New South Wales coals, whilst, being non-caking, it crumbles in the furnaces to some extent, and requires a certain amount of increased attention in firing. That from some of the seams has been found rather prone to spontaneous combustion. The Collie coal, although not of the best steam-producing quality, when burned in ordinary boiler furnaces, has been proved to be particularly suitable for use in suction gas producers.

The coal production of the State up to the end of 1912—which is entirely that of the Collie Coal Field—amounted to 2,323,136 tons, valued at £1,069,435 (Plate XIII.). The principal local consumers are the Government Railways and local manufactories; the goldfields market for coal is limited, owing to good firewood supplies being available.

60.—GEOLOGICAL OBSERVATIONS IN THE MULLINE, RIVERINA, AND ULARRING CENTRES, NORTH COOLGARDIE GOLDFIELD.

By F. R. FELDTMANN.

With two Maps (Plates XIV. and XV.) and 29 Figures.

CONTENTS.

A BRIEF DESCRIPTION OF THE COUNTRY BETWEEN KALGOORLIE AND MULLINE.		PAGE
Introduction		106
The Greenstones		107
The Granites		108
The Country between Kalgoorlie and Mulline		108
Notes on the Country near Mulgarrie		128
 (GEOLOGICAL OBSERVATIONS IN THE MULLINE, RIVERINA, AND ULARRING MINING CENTRES.		
I. General Remarks		132
II. The Rocks		133
(1.) Amphibolites		133
(2.) Granite		134
(3.) Acid Intrusives		134
(a.) Granite-Porphry		136
(b.) Quartz-Porphry		137
(c.) Pegmatites		140
(4.) Basic Intrusives		144
(5.) Recent Superficial Deposits		145
(a.) Laterites		145
(b.) Sand, Loam, etc.		145
III. The Ore Deposits		145
(1.) Primary		145
(a.) Quartz Reefs		145
(b.) Lode Formations		150
(2.) Secondary		151
IV. Evidences of Dynamic Action		151
V. Relative Ages of the Rocks and their Relationships to each other and to the Ore Deposits		153
Appendix I.—Returns from Leases		154

A BRIEF DESCRIPTION OF THE COUNTRY BETWEEN KALGOORLIE AND MULLINE.

This description has been compiled from notes taken during May and June, 1914, when the writer accompanied the Government Geologist, Mr. A. Gibb Maitland, on a trip to Mulline, in order to

make a brief examination of the surrounding country with a view to considering the advisability of boring for new auriferous deposits in that district.

Although the main object of the trip was the question of boring at Mulline, it was considered advisable to digress considerably from the most direct route in order to roughly map in the boundaries between the main granite masses and the rocks of the auriferous series—for which the general term “greenstone” has been adopted—between Kalgoorlie and Mulline. These are shown on the general map of the area traversed (Plate XIV.).

The Greenstones.

The greenstones consist for the most part of amphibolites and epidiorites (derived from dolerites or gabbros), in places altered to hornblende schists, and, further, to chloritic rocks; hornblendite (derived from pyroxenites)—this type is less common; and serpentines, tale-chlorite, and carbonate rocks. The original forms of the three last are rather obscure; the serpentines may have been derived from peridotites, but their structure and general appearance, as shown in section, point rather to their derivation (with the possible exception of the Gordon rock) from rocks rich in hornblende or augite, such as hornblendites or pyroxenites; the tale-chlorite rocks may have been derived either from serpentines or more directly from hornblendites, most probably from both, whilst the carbonate rocks may have originated by more complete alteration from any of the other types.

For convenience the greenstone series may be divided into:

- (a) the Kanowna-Mulgarrie belt;
- (b) the Bardoc belt;
- (c) the Ora Banda belt; and
- (d) the Dayhurst-Mulline belt.

No particular shape is implied by the use of the term “belt.”

(a) The Kanowna-Mulgarrie belt, which includes the Six-Mile group of leases to the west of Kanowna, runs west of north from the latter place, past the Gordon and beyond Mulgarrie. The northern and eastern boundaries of this belt have not been encountered. It includes amphibolites and quartz-carbonate-fuchsite rocks at Kanowna; rocks ranging probably from amphibolite to serpentine and carbonate rocks near the Gordon; and amphibolite and tale-chlorite rocks at Mulgarrie.

(b) The Bardoc belt has not been mapped south of Paddington; going south it joins the Ora Banda belt about 4 miles south of west from Broad Arrow and possibly links up with either or both of the Kalgoorlie and Kanowna series. It runs about north-north-west from Paddington through Broad Arrow, Bardoc, and Vetersburg, averaging about 7 miles in width; its further continuation to the north has not been mapped. It includes serpentines, amphibolites,

and tale-schists at Paddington; amphibolites at Broad Arrow and Bardoe; serpentine and carbonate rocks at Vettorsburg.

(c) The eastern boundary of the third belt has been roughly mapped from its junction with the Bardoe belt to where it crosses the Canegrass-Waverley road: the only point where its western boundary has been mapped is on the Waverley-Wangine Soak road. It includes amphibolites, serpentine, and porphyrite (shown in separate colour on the map) at Ora Banda; the Waverley rocks have not been examined in detail. This belt appears to run as far south as Kunanalling, and may possibly join up with the Coolgardie belt.

(d) The Davyhurst-Mulline belt has been mapped in more detail than the others—its approximate boundaries can be seen on the map; the centres of Davyhurst, Mulwarrie, Ularring, Mulline, and Riverina are on this belt, which does not appear to be so highly basic as the others, consisting almost entirely of amphibolite with occasional small areas of hornblende schist.

The Granites.

The granite areas may be divided into:

- (a) the Reserve 3092—Split Rocks belt;
- (b) the Canegrass belt;
- (c) the Wangine-Ularring belt.

All probably consist for the most part of biotite-microcline granite. At Reserve 3092 the rock is much coarser in grain than usual, with very large felspar phenocrysts, and may be of different age. Areas of quartz or felspar-porphyry also occur. The southern boundary of the first belt has not been traced, but probably does not run far south of the chain of dry lakes running between the 39-mile peg on the Kalgoorlie-Broad Arrow road and the 44-mile peg on the Kanowna-Mulgarrie road. The second belt appears to tail out to the west of Broad Arrow; its boundaries have not been mapped north of Canegrass. The Wangine-Ularring belt probably forms part of the large granite area shown on Plate II. of Bulletin No. 45 of the Survey.*

The Country between Kalgoorlie and Mulline.

We left Kalgoorlie on the 26th May for the Gordon, our means of conveyance being buggy and pair. Owing to several minor break-downs, due to the unavoidably heavy load and the heavy track, we did not reach the Gordon water reserve till the morning of the 28th. There is a small tank with dew catchment on this reserve. The necessity of sending the buggy back to Kanowna for repairs enabled Mr. Maitland and myself to briefly examine the breakaways on the western side of the lake extending southwards from the Gordon. These breakaways, so far as examined by us, consist largely of rocks

* "The North Coolgardie and East Murchison Goldfields," by H. W. B. Talbot.

of a highly basic character, resembling in external appearance the altered peridotite of Hamman's Lake, about 7 miles south of Kalgoorlie. The greenstones are intersected by large dykes of quartz-porphry forming hog-backed ridges of considerable altitude, particularly at the northern end of the lake. The porphyry appeared to consist of two main ridges with, probably, the usual N.N.W.-S.S.E. strike and with occasional spurs running more or less at right angles to the main ridges. A few cross quartz veins in the porphyry, dipping in a northerly direction at about 60 degrees, have been worked for their gold contents. The porphyry itself is a fine-grained pale yellowish rock with characteristic blocky structure. A narrow band of greenstone forming the thalweg between the main ridges could be traced both by rock debris and by the growth of morrell, gum, and saltbush—the porphyry carrying chiefly mulga, sheoak, and hop-bush with occasional kurrajongs. There appeared to be few external signs of contact metamorphism present.

At the Gordon itself, and for some distance along the eastern side of the lake, the country consists largely of rocks of a highly schistose character, some of them closely resembling a highly sheared porphyry.

The geological features of Kanowna have already been described in detail by Messrs. Blatchford and Jutson in Bulletin No. 47, and no description need be given here.

We left the Gordon early on the 30th May and reached Mulgarrie shortly after noon, camping at the water reserve, where there is a tank with dew-catchment similar to that at the Gordon.

The country between the Gordon and Mulgarrie is of a slightly undulating character and consists of greenstone, schistose in places, carrying morrell and gimlet gums. Round the Mulgarrie Water Reserve the vegetation consists almost entirely of the larger variety of mulga. Near Mulgarrie the greenstones, which appeared in such examples as the writer was able to examine to be highly talcose, have been intruded by occasional acid dykes. Some lateritic debris was also observed.

After our return to Kalgoorlie from this trip the writer was able to pay a flying visit to Mulgarrie, the results of which are given at the end of this report.

The following day we proceeded westward for about five miles along the Mulgarrie-Bardoe road, striking granite country about two miles west of Mulgarrie; this was the eastern boundary of the Split Rocks belt, which extends westward to within three miles of Bardoe. We then turned in a generally northerly direction to strike an old timber tramway which runs north from near the Mulgarrie-Bardoe road for about five miles and then runs west past Split Rocks. There were no signs of this tramline near the road, but eventually

we struck a spur line from it, about $3\frac{1}{2}$ miles north of the road, and thence followed the main line to its terminus. The country was largely obscured by the usual covering of soil, but, from the character of the latter, appeared to consist chiefly of granite; in one instance a small lens of greenstone was observed, a little south of the bend of the line, but whether an isolated lens of the auriferous series or a later intrusive dyke, it was impossible to say from such brief inspection as was possible while on the track. We were unable to find Split Rocks in the position marked on the map, and the tramline also appears to continue for a considerable distance further west. At about $2\frac{1}{2}$ miles west of the terminus of the timber line we descended a small breakaway running more or less north and south, and facing west, the lower lying country beyond it being covered with a fairly dense growth of gimlet saplings.

The next day (1st June) we struck the Bardoe-Yerilla road at about five miles from the former place to which we proceeded, crossing the eastern boundary of the Bardoe greenstone belt about three miles north-east of the town; the junction between the two rocks was entirely obscured and its position could only be judged approximately by the character of the soil and the decomposed rock debris.

In the Annual Report of the Survey for 1899 a brief account of the geology of the Bardoe district is given by Mr. Blatchford, Assistant Geologist. He describes the superficial alluvium of the district as being underlain by massive hornblende rocks, intersected by acid dykes. These hornblende rocks, are, he states, in most instances fine in grain, but one instance is given where remnants of well-developed feldspars could be seen forming a large proportion of the rock. He further states that the quartz reefs of the district almost invariably occur in the vicinity of the acid dykes, free quartz sometimes forming a stock-work in the dykes themselves, enabling them to be profitably mined.

From Bardoe we followed the road running north, by the railway line, as far as Vettensburg where we camped early in the afternoon, the rest of the day being spent in examining the dumps in the vicinity which consisted largely of serpentine [13822]* together with a dark grey carbonate rock [13823] probably derived therefrom. An easterly-dipping quartz reef of fair size and somewhat icy appearance [13825] runs through the old Argyle and Vettensburg leases on which a good deal of work has been done. On the walls of the reef were numerous pale bluish-grey silky radiating clusters of actinolite [13824] rapidly weathering, on exposure, to a pale blue clay. At the southern end of the reef and on the west side of it a small intrusive dyke was seen to outcrop, a specimen of which was described by the Petrologist, Mr. R. A. Farquharson, as

* NOTE.—The figures in brackets refer to specimens in the Geological Survey collection.

a hornblende (diorite) porphyrite, [13826], seen in section to consist of:—

“Numerous squarish turbid phenocrysts of felspar in a more or less minutely platy felspathic ground-mass in which needles and thin prisms of brownish green hornblende are very common, and in which there are frequent small curved wisps and minute fibrous sheaves of the same mineral.

Many of the larger hornblende plates have a distinct fibrous fringe. Quartz was not determinable among the phenocrysts, but with high powers, it is recognisable in some irregular plates in the ground-mass. The latter also then appears to consist in part of a micro-mosaic of indeterminable constitution.”

Leaving Vetersburg we continued northwards along the railway line as far as Canegrass siding, crossing the eastern boundary of the granite belt about two miles below the siding. From Canegrass we proceeded south-westward along the Waverley road over a succession of sand-covered granite ridges carrying spinifex and small gums with occasional patches of cypress and native poplar. A small quarry close to the road about three miles from Canegrass disclosed a white granite with coarse felspar crystals and very little biotite. No other outcrops of the granite were seen, and the western boundary of this belt was obscured, but judging from the nature of the soil should pass close to the five-mile peg. From thence on to Waverley the country appears to be entirely greenstone and the road is much better. Near Waverley itself the country is more hilly and there are numerous outcrops. A few nodules, apparently of magnesite, were seen, so that in places the greenstone is evidently pretty basic in character. Several of the hills are capped by laterite, a highly ferruginous variety occurring near the south-east corner of Water Reserve 4251 (the Waverley dam) where we camped for the night. We found the dam to contain a fair amount of water.

The following day we passed through Waverley township and struck the eastern boundary of the Wangine granite belt at a little over a mile from the town. A small patch of mulga was passed through near the eastern edge of this belt, but from thence to within a couple of miles of the Wangine Soak there is a flat stretch of country carrying fine salmon and gimlet gums and saltbush (Fig. 6). Between this and the Soak is a small bleak salt-lake about half a mile in width. We did not stop at the Soak on the outward journey, but on the return journey an opportunity was taken of examining the fine breakaways in the vicinity and of taking a few photographs—a description of the breakaways being given later on in this report. From the Soak we proceeded along the road to Callion (Speakman's) over the higher granite country beyond the breakaways. The bush was very monotonous, consisting almost entirely of low mulga with, occasionally, a little cypress. Progress was slow, the road being very sandy till about the 81-mile peg, where the vegetation also improves, a few gums coming in. We camped for the night between the 84 and the 85-mile pegs.

The road crosses the south-eastern boundary of the Dayvhurst greenstone belt between the 84 and 85-mile pegs, a schistose structure being noticeable near the junction. Some prominent white

Fig. 6.



Photo., F. R. Feldtmann,
 Neg. F163.
 Salmon Gum and Salt Bush country, between Waverley and Wangine Soak, Broad Arrow G.F.

"buck" quartz reefs of the granitic type lie close to the road near the 86-mile peg.

Between the eastern boundary of the greenstone belt and the Callion is some well-timbered country carrying morrell and gimlet gums, broom and saltbush. We found the centre practically deserted with the exception of some cattle. Of the two dams the one

Fig. 7.

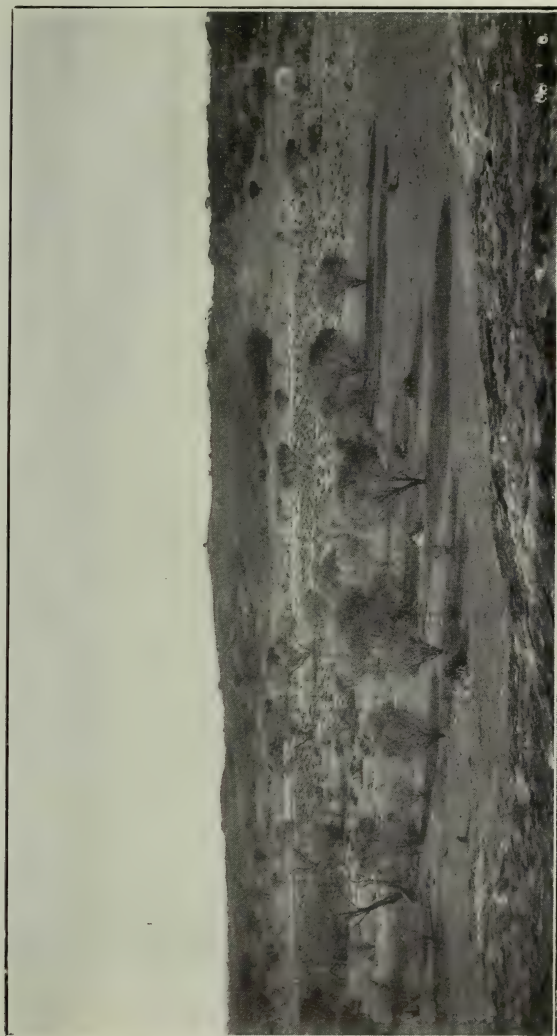


Photo., F. R. Feldtmann.

Trig. Station, Ularring Rocks, North Coolgardie G.F.

Neg. F152.

contained a little water, the other was dry. The south-western boundary of the greenstone belt appeared to be a little to the west of the townsite, a spur of the granite crossing the Mulwarrie road between

the 91-mile and the 92-mile pegs. The water in Speakman's Well contained a good deal of mineral matter and was most unpleasant to the taste; the rock on the dump appeared to be a highly biotitic

Fig. 8.

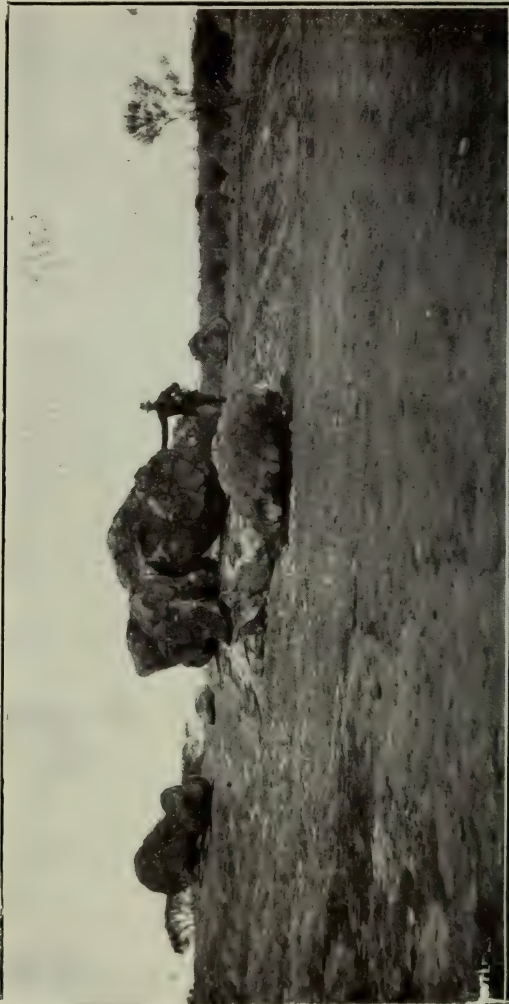


Photo., F. R. Feldtnann.

Showing weathering of Granite, Ularring Rocks.

Neg. F154.

gneissic granite. Between the 92-mile peg and Mulwarrie the road runs through undulating greenstone country, covered, in places, with laterite debris. Mulwarrie itself appeared to be very quiet.

From Mr. Gibson's description,* the country around Mulwarrie closely resembles that round Mulline, there being a number of

* G.S., W.A., Bulletin, No. 12 (out of print.).

granite porphyry and quartz porphyry dykes, whilst the quartz reefs occur in narrow bands of hornblende schist and, in most cases, dip at a shallow angle.

Fig. 9.



Photo., F. R. Feldtmann.

Neg. F155.

Small Gnamma Hole, along a Quartz Vein, Ularring Rocks.

Between Mulwarrie and Ularring the road strikes granite country near the 102-mile peg and runs through it until just before the 107-mile peg. Between the 103-mile and 104-mile pegs a track

turns off to the Ularring Rocks, on which is a Trig. cairn at just under half a mile east of the main road. (Fig. 7.) The Trig. station is on a large bare granite mass, rising fairly steeply from the flat on its western side; other smaller patches of bare granite also occur near the main hill, examples of the "tors" associated with the weathering of granite masses are to be seen on these. (Fig. 8). The vegetation in the vicinity is nearly all mulga.

The rock itself [5014] is of medium grain and is described by Mr. Farquharson as a biotite-microcline granite. In addition to the microcline, a finely twinned plagioclase feldspar is present. Some shapeless fresh feldspar forms show a vermicular intergrowth with quartz. In some of the feldspars are large flakes of muscovite.

Veins of pegmatite consisting chiefly of coarse feldspar and quartz are not uncommon—one two feet in width being observed by the writer. The usual strike of these pegmatites was about 20 degrees east of north. Of later age than the pegmatites and cutting across them was a series of thin quartz veins striking about 16-20 degrees west of north. Along one of these veins was an excellent example of a small elliptical gnamma hole—the quartz vein forming the major axis of the ellipse. (Figs. 9 and 10.)

There was no water on the rock, and the two soaks to the west of it were dry, but good water was obtained from a well about half a mile south-west of the Trig. station.

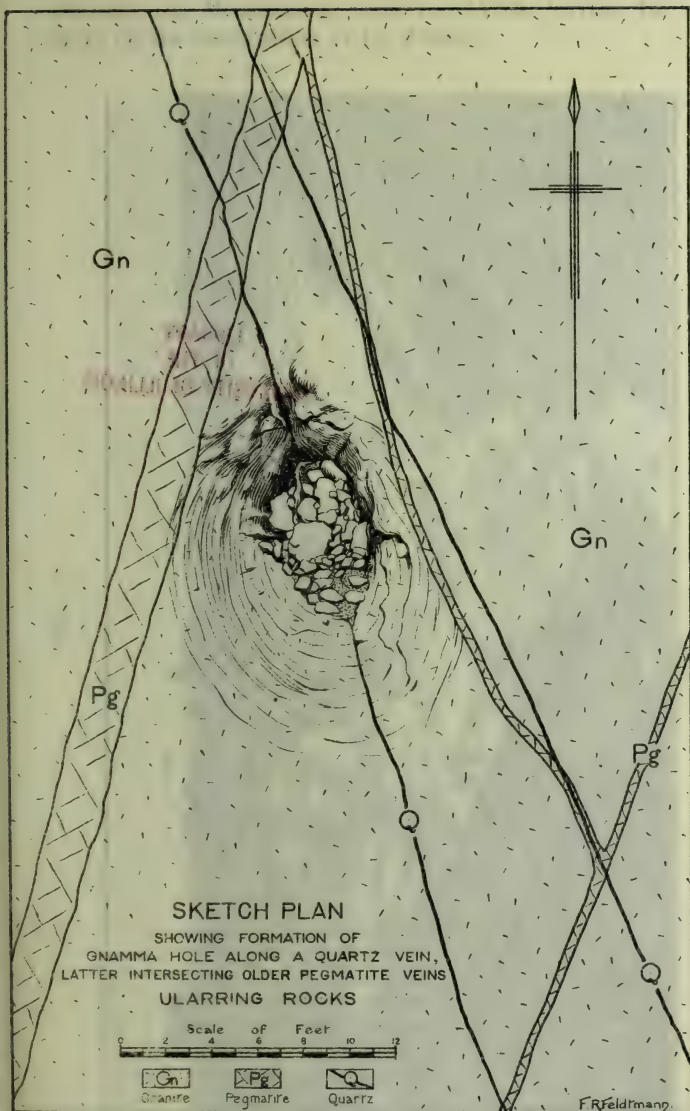
Leaving Ularring Rocks we struck the main road again just before the 104-mile peg. Some fine granite boulders were seen to the west of the road between the 105 and 106-mile pegs, and the top of the granite ridge was crossed shortly after. We reached greenstone country just before the 107-mile and continued through it from thence on.

Between the Ularring centre and Mulline is a stretch of fairly open country carrying morrell and a few gimlet gums, and salt-bush.

There being no supply of water at Mulline—the dam on Reserve 5068 being dry—we pushed on to Riverina, where there is a small windmill with tank and trough, and camped about a quarter of a mile west of the tank. Fresh water is obtainable in the Riverina group of mines.

The geological features of the Mulline, Ularring, and Riverina centres are described on a later page of this report and need not be discussed here.

We camped at Riverina from 5th to 15th June, during which period we briefly examined practically everything of importance at Mulline and Riverina. On 15th June we broke camp and proceeded to Ularring, where it was intended to spend a couple of days before starting on the return journey. When passing through Mulline, however, Mr. Maitland received word that his attendance was re-



H. J. Pether, Government Lithographer, Perth, W. A.

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quired at the Interstate Conference on Artesian Water, held at Brisbane. This necessitated his departure early the following morning for Menzies, *en route* for Perth, leaving the writer to finish off the examination of the district.

Fig. 11.

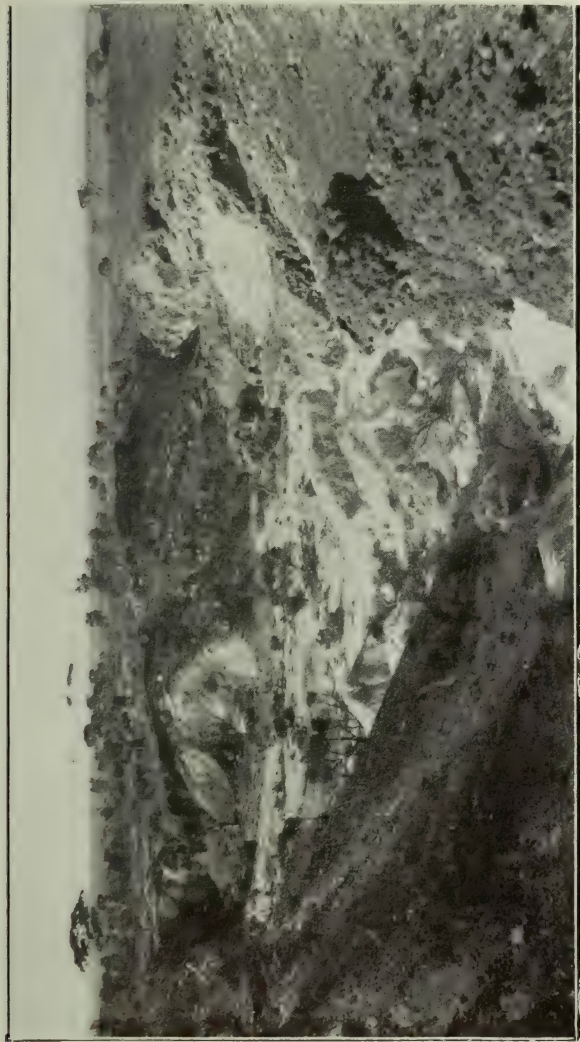


Photo., F. R. Feldtmann.

Breakaways, Wangine Soak, North Coolgardie G.F.

Neg. F156.

Showing darker laterite cap above white kaolinic matter and the cutting back of cliff by watercourse.

Having finished my examination of Ularring on the morning of the 18th, we left that afternoon for our former camp at Ularring Rocks.

On the 19th we proceeded towards Davyhurst, through granite country, partly obscured by soil and laterite debris, and carrying chiefly mulga with a little gimlet-wood, to within about a mile from the Mulwarrie-Menzies road, where as far as could be judged from

Fig. 12.



Neg. F158.

Breakaways, Wangine Soak, North Coolgardie G.F.

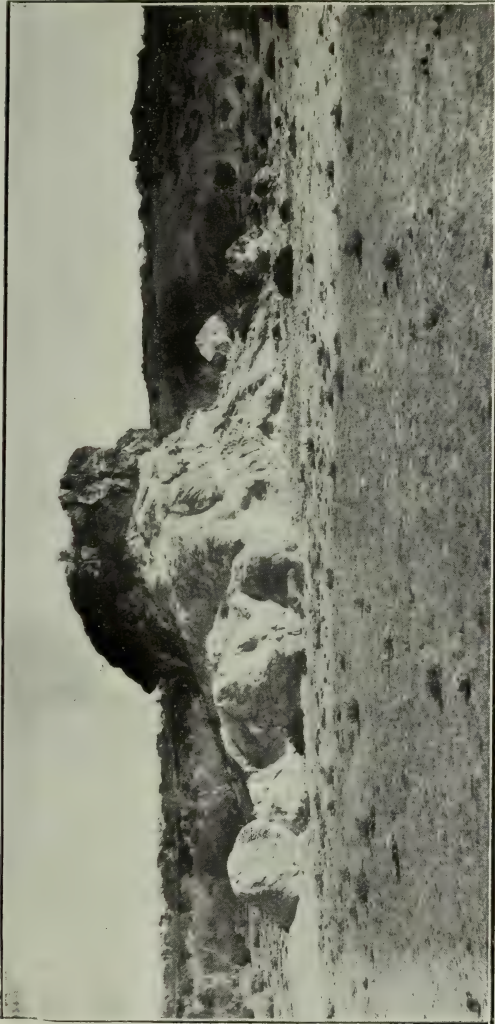
Showing gradual passage of ferruginous matter into laterite cap.

Photo., F. R. Feldtmann.

the soil, greenstone comes in again. South of the road the country was fairly open. We reached the Davyhurst dam about noon; the dam then held about 13 feet of water.

From Davyhurst we travelled in a generally easterly direction for about three miles, gradually turning south-east, along the Wangine Soak road—the road running through greenstone country until

Fig. 13.



Neg. F157.

Outlier, Wangine Soak.

Photo., F. R. Feldtman.

about three and a half miles from the town, at which point a few granite pebbles were observed and the track became very sandy from thence on to the Soak being one of the worst bits encountered on the trip. The vegetation was almost entirely mulga and spinifex, with an occasional cypress, but a few small patches of

morrell gum and broombush on darker soil with some travertine suggested the possibility of small lenses of greenstone. After a very heavy day we reached the soak late in the afternoon and there camped.

Fig. 14.



Photo., F. R. Felitmann.

Breakaways, Wangine Soak.

Showing peculiar weathering of laterite.

Neg. F159.

The following morning was spent in examining the breakaways round the soak. These breakaways form a rough semi-circle the diameter of which runs in a north-easterly direction, the cliffs

facing inwards. The cliffs reach a considerable height above the lower ground and are particularly fine, especially at the northernmost corner where a series of watercourses has cut into the cliff for a hundred yards or so, forming a gulf off the main bay. (Fig. 11.)

The original rock forming the breakaways has been completely weathered and is almost impossible to determine on a brief examination. From the general character of the breakaways and of the country above, however, it appears to have been granite. The cliffs have a capping of reddish-brown laterite, of the type usually found on granitic rocks, a few feet in thickness. Below this cap is kaolinic matter containing numerous quartz grains and dazzlingly white in places, especially round the small "gulf" previously mentioned, where it forms a striking contrast to the brown laterite. In places a gradual passage upwards of the ferruginous matter into the laterite can be observed (Fig. 12); whilst in others, especially in some of the small outliers, the rock at first sight resembles a kaolinic sandstone or grit (Fig. 13); certain layers of coarser material probably represent decomposed veins of pegmatite. The softer kaolinic material being the more susceptible to the action of the wind and water, weathering has resulted in the formation of fantastic shapes, whilst the laterite itself has weathered in places to forms resembling the bases of broken columns (Fig. 14).

At the easternmost corner of the previously mentioned "gulf"—the extreme left of the photograph (Fig. 11)—a watercourse has exposed lenses of weathered and apparently schistose greenstone in the still more weathered granite. These lenses are shown fairly clearly in the photograph (Fig. 15), one lens occurring in the centre of the view, and another slightly to the left of and beyond the first. The greenstone appeared to be of the usual doleritic character and of medium grain, whilst the schistose appearance of the outcrops is probably due to latent schistosity shown up by weathering. As to the relationship between the two rocks, while it is impossible to come to any definite conclusions on the available evidence, from their apparent resemblance to the rocks of the auriferous series, it is probable that the greenstone lenses represent portions of a larger mass which remain unabsorbed by the intrusive granite. Unfortunately, time could not be spared to examine the further continuation of the breakaways to the north-east.

About ten chains west of the old inn, and crossing the telegraph line near the top of the breakaway, is a large white "buck" quartz reef striking north and south, and dipping west at about 65 degrees. This reef could be seen along the top of the western escarpment for a considerable distance.

We left the Soak after lunch, reaching the Waverley dam late in the afternoon, and the following day proceeded to Ora Banda. Past Waverley the country is chiefly greenstone, but a small patch of granite was observed to the east of the track, about two miles

north of the Christmas group of leases. Between the granite outcrop and the Christmas leases and about quarter of a mile west of the road to Ora Banda is a series of three hog-backed

Fig. 15.



Photo., F. R. Feldtmann.

Breakaways, Wangine Soak.

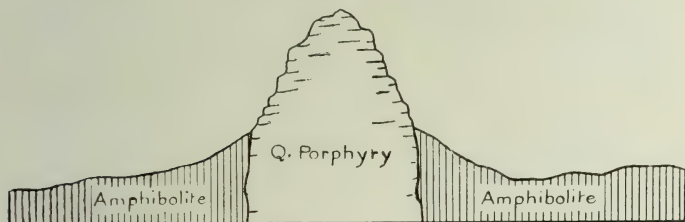
Lenses of greenstone in decomposed granite exposed by watercourse.

Neg. F160.

ridges of quartz-porphyry, striking approximately west-north-west and rising abruptly out of the flat greenstone plain. In appearance, the ridges resemble those of the Gordon, the rock itself being slightly coarser in grain; it has the usual blocky structure. The superior hardness of the rock has enabled it to resist weathering

more successfully than the surrounding greenstone, resulting in its present striking appearance (Fig. 16). Between these ridges and the town of Ora Banda, the country appeared to be greenstone, but with the exception of some laterite, no outcrops were observed. The country to the east is more hilly.

Fig. 16.



Near Christmas Gp., Broad Arrow G.F.

Showing relative weathering of amphibolite and intrusive dyke of quartz porphyry.

The geology of Ora Banda has been described in detail by my colleague, Mr. J. T. Jutson.*

The town itself appeared to be the busiest encountered during the trip.

From Ora Banda we proceeded past Cashman's and left the Broad Arrow road near the 45-mile tank, travelling in an east-north-easterly direction towards Bardoe. Shortly after passing the "Bunyip" mine, the western boundary of the Canegrass granite belt was crossed and morrell and gimlet gums and broom bush gave place to mulga and occasional kurrajong. Along this section the granite belt is only about four miles wide, the Bardoe greenstone belt then coming in. No greenstone outcrops were seen, but some highly ferruginous laterite was crossed. We camped for the night about a mile to the west of Bardoe.

Passing through Bardoe we proceeded along the Mulgarrie road. The vegetation at first consisted of morrell and salmon gums with broom and saltbush, and some lateritic debris was observed. Just before the 65-mile peg, the soil becomes more granitic and the vegetation consists of mulga with native grass and some spinifex and a little sheoak. Near the 62-mile the country is more open. Some distance past the 61-mile we turned south along the old timber tramway, which we followed for nearly two miles. As the line was then running in a south-westerly direction, we turned south through the bush, reaching the Broad Arrow-Mulgarrie road, a little east of the 7-mile peg. We followed this road as far as the

* G.S., W.A., Bulletin, No. 54.

8-mile, where another old tramline runs south. This we followed for about three miles to its terminus, continuing on our way south for about another mile, when we turned south-east towards the large rock hole on Water Reserve 3092. The rock hole is situated at the end of an arm running north from the chain of dry lakes stretching from Black Flag to the Gordon. On a visit paid by Mr. Maitland during the previous year, the rock hole was full of water, but, owing to the excessively dry season and the depredations of cattle, we found it quite dry. The granite outcrops on the north-western side of the rock hole are remarkable for the large felspar (orthoclase) crystals, which reach nearly three inches in length; as the surface of the granite weathers the crystals stand out as knobs. The surface of the crystals is much pitted, somewhat spoiling them as specimens. Carlsbad twins are common.

The following is a description of the granite itself by the Petrologist:—

“[13804]: A grey coarse-grained granite with large porphyritic crystals of felspar and scales and books of blackish biotite. The phenocrysts, as usual in porphyritic granite, are orthoclase.

There are numerous square or rectangular, almost phenocrystal and certainly mostly idiomorphic, crystals of highly kaolinised felspar, between which are shapeless plates of clear quartz less numerous than the felspars. Flakes of brown biotite occur sparingly. The felspar species appears to be mostly about oligoclase but some orthoclase also seems to be present. The kaolinisation and micacisation of the mineral render determination extremely difficult.

There is a simulation of zonal structure in the alteration, a kaolinised zone succeeding a fresh rim in several of the felspars. The quartz is frequently interstitial, though occasionally in large platy forms. The plates appear in places to be broken up into optically continuous portions, and irregular extinction is common.

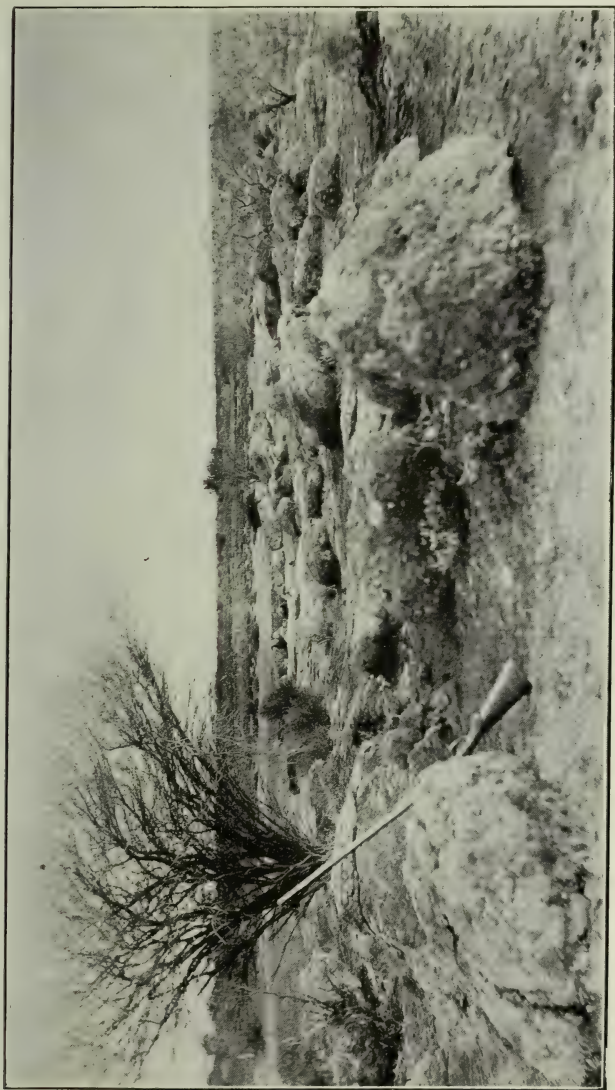
The structure of the rock is intermediate between that of a granite and a granite-porphry; there is no true ground-mass, but idiomorphic felspars are associated with interstitial platy quartz.

The rock is a porphyritic biotite granite.”

A few lenses of a much finer grained grey rock, distinctly schistose at their edges, were seen in the granite. These lenses, which appeared to be about fifty feet in length, strike approximately east and west. The rock was fairly weathered. Of two specimens, [13805] and [13806], examined by the Petrologist, one showed quartz phenocrysts, which were absent from the other—there were numerous felspar phenocrysts in both, some being orthoclase, others an acid plagioclase, biotite was also present; the ground-mass consisted of small plates of felspar and quartz with small scales of biotite. The structure is porphyritic and the rock is classified as a quartz porphry. One of the specimens showed distinct evidence of having been sheared after consolidation. Owing to their difference of structure, these lenses and the granite cannot be considered as portions of the same mass—the junction, too, between them is fairly sharply defined. Which rock is the older it is impossible to say on the evidence available (Fig. 17).

Leaving the rock hole, we proceeded northwards along the timber line to the 8-mile peg, and thence followed the road to Broad Arrow.

Fig. 17.



Neg. F165.

Water Reserve 3092, Broad Arrow G.F.

Showing outcrop of coarse granite with large feldspar crystals.

Photo, F. R. Feldtmann.

The vegetation at first consisted of sheoak and gimlet wood with some quandong and broom, giving place to mulga near the 6-mile peg—the first mentioned type being again in evidence at the

5-mile, dense mulga with a little kurrajong coming in shortly after. The soil throughout appeared to be of granitic origin.

The western boundary of the granite passes fairly close to the 2-mile peg, near which the greenstone is seen to outcrop, apparently somewhat schistose near the junction.

We crossed the railway line at Broad Arrow and then turned southwards towards Paddington.

The geological features of Broad Arrow appear to be similar to those of Bardoc in every way.

About a mile north-west of Paddington railway station and immediately west of the road from the Broad Arrow Water Reserve, we passed a small quarry exposing a soft, purplish, fissile rock,—the laminae striking approximately 18 degrees west of north and dipping to the west at about 80deg. Petrological examination showed the rock [13807] to consist of granular hæmatite, quartz

Fig. 18.

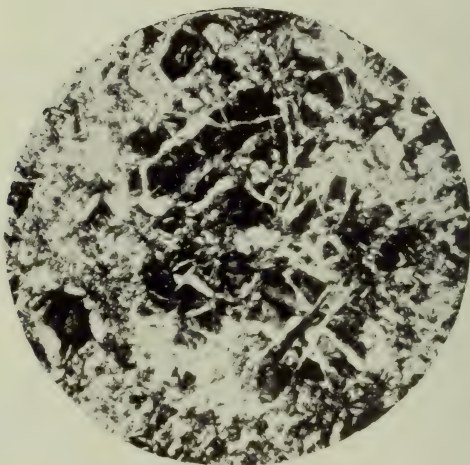


Photo., R. A. Farquharson.

Neg. 1204.

Microphotograph 13809, Serpentine.

granules, and some minute micaceous scales. Although externally resembling a rock of sedimentary origin it is possible that the rock represents a highly weathered and sheared greenstone. Greenstone was seen in a small cutting about seven chains north of the station. Beyond the town and a few yards north of the 44-mile peg, an outcrop of hard, fine-grained greenstone [13809] was seen crossing the road. The rock is of a dull green colour and though hard to

the hammer is easily scratched by the knife. Its appearance is distinctly that of a serpentine. The following is the Petrologist's description:—

"[13809]: In section, the rock consists of a pale yellowish-gray mass which, in polarised light, shows up in places as a fine grained network, and in others as irregular platy areas of a mineral of very low birefringence, with scattered small patches of a highly polarising material. Under high powers, the rock is made up of some yellowish, almost isotropic plates, but mostly of irregular and extremely minutely fibrous plates of low birefringence, some with bastite appearance and of more or less confused arrangement. There are some areas of a clear, scaly, highly polarising mineral. The predominant mineral is referred to fibrous serpentine, with a small amount of the laminated variety; the highly polarising scaly patches represent aggregates probably of talc: there are some grains of calcite, and apparently some chloritic scales, with difficulty distinguishable from serpentine. Only in places is there any approach to the granular structure of those serpentines derived from olivine. The general structure of the rock is irregular scaly fibrous, though occasional isotropic chloritic areas occur that probably represent an original hornblende or augite.

The rock is a dark-green fibrous serpentine, derived apparently from a rock rich in hornblende or augite rather than olivine. Both in external appearance and in microscopic structure and composition, there is a close resemblance between this rock and [13822] from Vettersburg." (Fig. 18).

A large dump on the eastern side of the road close to this outcrop consisted largely of talc-carbonate schist, some large fragments of quartz, and some carbonates, sericite and possibly fuchsite were also seen.

The road to Kalgoorlie crosses over to the eastern side of the railway line between the 43 and the 44 mile pegs, and the main track apparently leaves the surveyed road (as shown on the maps) near the 43 mile. Near the 41 and 42 mile pegs is a steep hill, the backbone of which is a huge white quartz "blow." A small tunnel driven for about 100 feet into the western side of the hill discloses a highly laminated talc-schist. On the western side of the quartz "blow" traces of a fine-grained rock—possibly a porphyry—were seen.

The country gradually falls to the southwards and the Black Flag-Gordon chain of dry lakes was met a little beyond the 40-mile, near which we camped.

We then proceeded in a direction approximately 10 degrees north of east to strike a dry lake shown on the map to the east of survey peg E9, in the hopes of finding breakaways similar to those near the Gordon.

Progress was necessarily slow, the country being very sandy. The vegetation at first was chiefly mulga and spinifex with a few small morrell gums, but soon after, small clay-pans and extensive samphire and saltbush flats, alternating with occasional sand and "kopai" dunes carrying sparse sheoak, cypress, etc., were met. The lake for which we were making was struck about 12.30 p.m. A good deal of detouring was necessary to avoid getting bogged in the numerous small arms running from the lake. After considerable

difficulty we reached the northern edge of the lake and continued eastwards along it, later getting up on to the higher ground. We found no breakaways, the banks of the lake being apparently composed of superficial deposits. Progress with the heavy buggy was exceedingly slow, even on the higher ground, where the surface was very sandy and the vegetation chiefly low scrub and spinifex, and it was late in the afternoon before we struck the Mulgarrie-Kanowna road near the 44-mile. Thence we followed the road into Kanowna, reaching the dam about 7 p.m.

On the 25th we left Kanowna, and proceeded to the Six Mile. The rock exposed on the dumps at this place is a hard, fine-grained, granular, dark greenish-grey greenstone, in which tiny white crystals of calcite are visible; the determination of a specimen being as follows:—

“[13810]: In section, the rock is a fine mixture of chloritic scales, few quartz plates, and grains of calcite. All evidence of structure has been obliterated. Under high powers, however, there are some forms that have some resemblance to small chloritic feldspars, but they are not definitely determinable.

The rock is a much altered fine-grained granular calcite-chlorite rock, perhaps of amphibolitic origin.”

The Six Mile rocks have been referred by Dr. J. Allan Thompson to the “fine-grained Amphibolites” (older series) in his classification of the Kalgoorlie rocks.*

From the Six Mile we turned south-west and presently struck a series of small hills, the backbone of which consisted of “jasper” reefs, about two miles east of the 33-mile peg on the Kalgoorlie-Broad Arrow road. With the exception of these hills the country consists for the most part of soil-covered flats, the soil having evidently been derived from rocks of basic character. We struck the road near the 32-mile peg and thence proceeded to Kalgoorlie.

Notes on the Country near Mulgarrie.

Early in July the writer had an opportunity of visiting Mulgarrie and of briefly examining some of the smaller mines in that locality.

The Mulgarrie centre was previously examined in 1899 by Mr. Blatchford, Assistant Geologist, in connection with the question of boring for water, and a brief description of the geological features was given by him in the Annual Progress Report for 1899. Mr. Blatchford's description is as follows:—

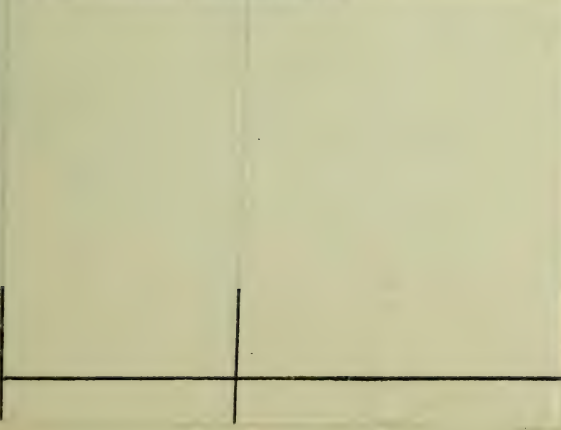
“Geologically, the Mulgarrie District may be described as consisting of hornblende rocks intersected by small felsite dykes, and overlain in most places by recent superficial deposits.

Alluvial Deposits.—These recent surface deposits cover the greater portion of the field, varying from a few inches to many feet (over 100 in places) in thickness. In composition they usually consist of loose red alluvial, intermixed with ironstone gravel and quartz pebbles, which overlies more compact

* Quarterly Journal, Geological Society, Vol. LXIX., p. 631.



Fig. 1. Saturated Vapor Pressure and Vapor Pressure of Water.



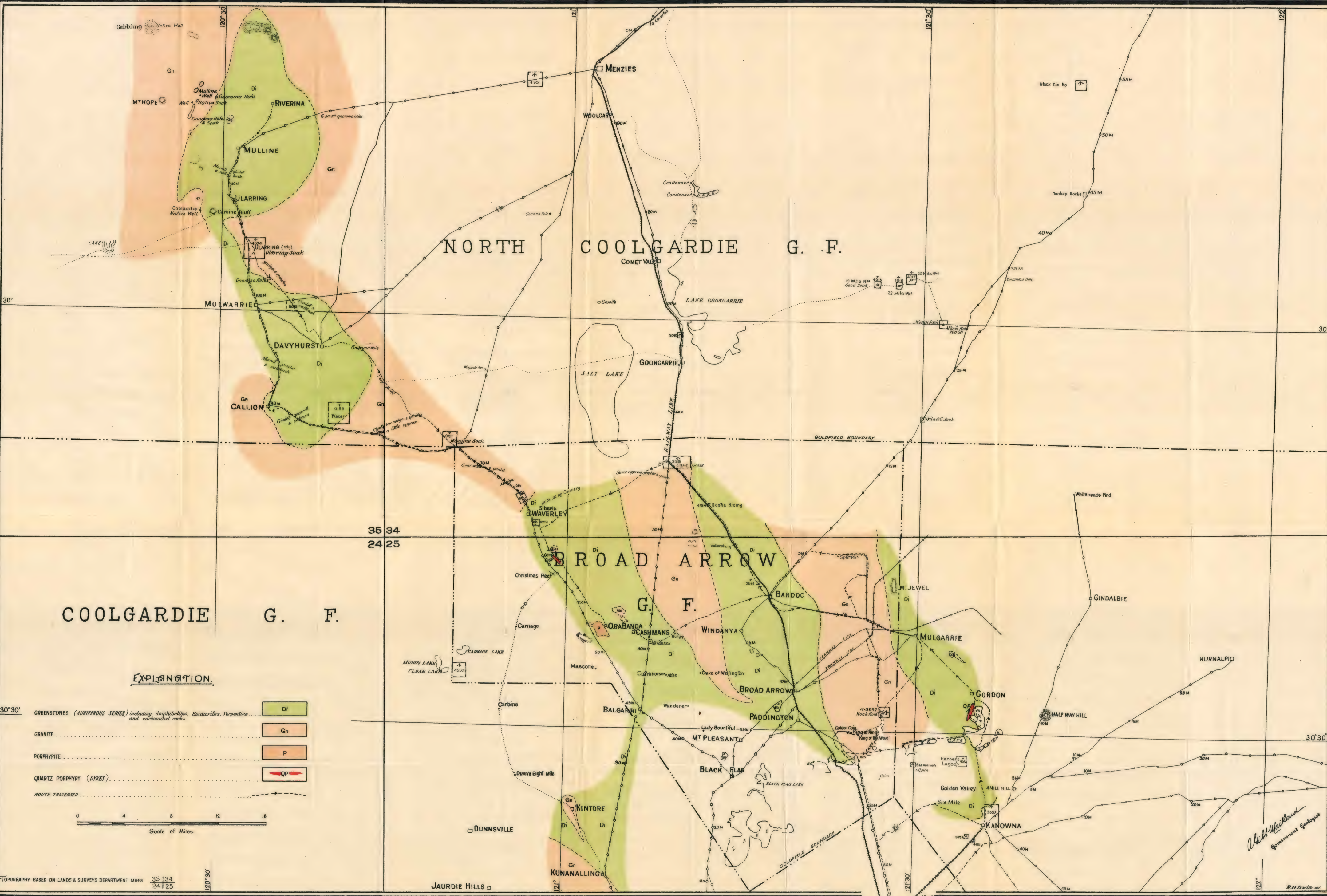


GEOLOGICAL SKETCH MAP
OF THE COUNTRY BETWEEN

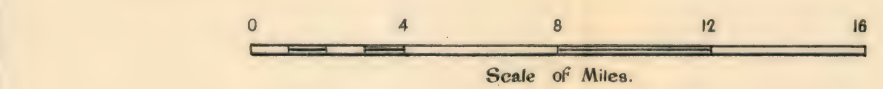
KALGOORLIE & MULLINE

BY
F. R. FELDLMANN
Field Geologist
1914

BULLETIN NO. 64, PLATE XV.



- EXPLANATION.**
- GREENSTONES (AURIFEROUS SERIES) including Amphibolites, Epidiorites, Serpentine and carbonated rocks. Di
 - GRANITE Gn
 - PORPHYRITE P
 - QUARTZ PORPHYRY (DYKES) QP
 - ROUTE TRAVERSED



TOPOGRAPHY BASED ON LANDS & SURVEYS DEPARTMENT MAPS 35 34 24 25

W. J. Fisher
Government Geologist

quartz and ironstone wash, the latter being frequently intermixed with, or overlying, beds of kaolin, commonly known as "pug." In appearance these beds closely resemble some of the alluvial deposits worked at Kanowna, their origin being very similar: but, unfortunately, up to the present payable wash has not been met with in the Mulgarrie beds. As far as could be ascertained, the maximum thickness of the deposits under notice is in excess of 100 feet, as that level was reached in some workings near Hayes' Consols (G.M.L. 657x), when further operations were stopped by an inflow of water. Scattered surface alluvial workings are to be seen in several parts of the field, and testify to the finding of surface gold, though in what quantities there is no available evidence. The prospecting in this respect, and also for "deep leads," has so far been carried on to a very limited extent.

Hornblende Rocks.—The hornblende rocks, which form the higher grounds to the north and south of the townsite, are usually in a more or less highly decomposed state. There are isolated cases, however, in which pieces of rock are found sufficiently unaltered to enable the principal rock-forming minerals to be detected in hand specimens. When such occasions offer, crystals of hornblende and felspar are seen to form the major portion of the rock; the proportion of hornblende exceeding the decomposed products are alone available for inspection, and as such, the prevailing colours of which are either yellow or brown. Specimens of very fine-grained compact rock are also to be found, but in such cases the constituent minerals are too minute to be distinguished with the naked eye. From their general appearance and habit, also their strong resemblance to certain rocks in the Coolgardie Goldfield, I have little hesitation in classifying these latter as diorites.

Acid Rocks.—Passing through the hornblende rocks, the outcrop of narrow dykes of acid rocks may be seen, trending usually north-west and south-east, with a prevailing dip to the east at a high angle. The thickness of these dykes does not usually exceed a few feet, though in isolated cases they widen out to at least three or four chains. They are apparently of a later age than the diorites. Hand specimens of the dyke rock show that the base is felsitic, and contains small blebs of felspar, invariably in a decomposed state, and minute grains of quartz. When weathered the outcrops exhibit an apparent cleavage, which runs parallel to the strike of the rock.

Granite.—On the Double Birthday Gift (G.M.L. 768x) is an outcrop of granite which extends over the greater portion of that lease, and is entirely different in general characteristics from the acid dyke rocks. In hand specimens of the granite, well-formed crystals of hornblende, mica, and felspar may be clearly seen, intermixed with larger blebs of quartz. The mica of this rock is mostly of special notice, as it possesses the pink tint similar to the lepidolite mica found on the Coolgardie and Murchison Goldfields. I was unable to discover at Mulgarrie any other outcrop of granite than the one above mentioned.

Quartz Reefs.—At the date of my visit to Mulgarrie there was but one reef being worked on the whole field, viz., the Hidden Treasure (G.M.L. 1056E). In consequence I was unable to see any of the underground workings, or to gather any information as to the nature of the reefs, etc., beneath the surface. On the accompanying plan, Plate II., the outcrops of the various lines of quartz reefs have been carefully drawn, from which it will be seen that the prevailing strike of the reefs is to the west of north, with an underlie either to the west or east. In general appearance most of the quartz is of a barren white appearance, and generally free from iron. There are exceptions, however, to this rule, and in addition to oxides of iron, oxide of manganese is sometimes present in considerable quantities. Closely associated with the quartz veins is a highly siliceous rock, banded with oxides of iron and resembling in nature the quartzites of the Murchison districts. There is little doubt that this banded rock has formed in the fissures of the diorite at a subsequent geological age to the quartz, as leaders of the latter are often found branching off from the main mass of quartz and penetrating into the quartzite (?). This mode of occurrence is clearly seen in the Hit or Miss Mine (G.M. 343E).

It is noticeable on the Mulgarrie Field that the quartz reefs, quartzites, and acid dykes are usually closely connected, and it is to be regretted that their exact relations to one another are not determinable owing to the limited amount of mining, and the fact that most of the outcrops are overlain with a mantle of alluvium.

From an economic point of view the quartz veins, though extensive, have so far been proved to be of an unpayable nature. In the Hit or Miss Mine (G.M.L. 343E) one rich patch of gold was struck in the large quartz reef passing through that property, but the reef taken as a whole, as far as it was opened out, proved to be of too low a grade to treat profitably. The same may be said of the "Black Reef," passing through G.M.Ls. 729E and 725E. Crossing this latter, however, small leaders are sometimes found (striking east and west), which carry payable gold, the richest portions of the leaders being at their junction with the main line of reef. Since my inspection of the field further attempts are being made to prospect the reefs at a greater depth, and to try and make the large low-grade ore bodies pay by treating them on a larger scale than was done formerly."

From Mr. Blatchford's description it would appear that the country rock of Mulgarrie is amphibolitic in character and probably derived originally from a dolerite or gabbro; further alteration might give rise, in places, to a talcose chloritic schist, such as was seen by the present writer at the Palm G.M.L. 1326x about half-mile east of the Water Reserve [13818].

At this mine the country rock is of a greenish-grey colour, fine in grain, soft, soapy in feel, and somewhat schistose. In external appearance it is not unlike the talc-chlorite rocks found at the North End of the Kalgoorlie field, but in section it more closely resembles some talc-tremolite-chlorite rocks from the Southern Cross district.

The formation worked at the above-mentioned mine was in the form of a stockwork of milky quartz, carrying free gold, occasionally somewhat flaky in character; a little crocoite (PbCrO_4) was present in some specimens shown the writer.

The stockwork appeared to be closely connected with an intrusive acid dyke, exposed in an open cut, but too highly decomposed for its exact nature to be determined.

On the return journey from Mulgarrie we left the main road near the 52-mile peg, turning south-west towards the rock hole on Water Reserve 3092. The western boundary of the Mulgarrie greenstone belt is obscured, but judging from the soil appears to be about two miles south-west of the 52-mile peg.

From the rock hole we followed the western side of the lake arm in a southerly direction. Occasional low breakaways were seen—composed of a highly decomposed and kaolinised granitic rock of medium grain, thinly capped with laterite. At about $1\frac{1}{2}$ miles from the rock hole we followed a track running more or less south of west, passing a number of fine kurrajong trees at what is locally known as the "Kurrajong Avenue," although the relative position of the trees in no way resembles that of an avenue (Fig. 19).

The former "King of the West" G.M.L. 709E, about three miles south-west of the rock hole, was passed shortly afterwards. The dumps on this mine were composed chiefly of fresh-looking

granite, partly also of a fine grained, pale grey micaceous and highly sheared rock with a more or less granular structure, though rare quartz grains suggest an original porphyritic. The rock bears some resemblance to the finer grained rock occurring in lenses near the rock hole.

Fig. 19.

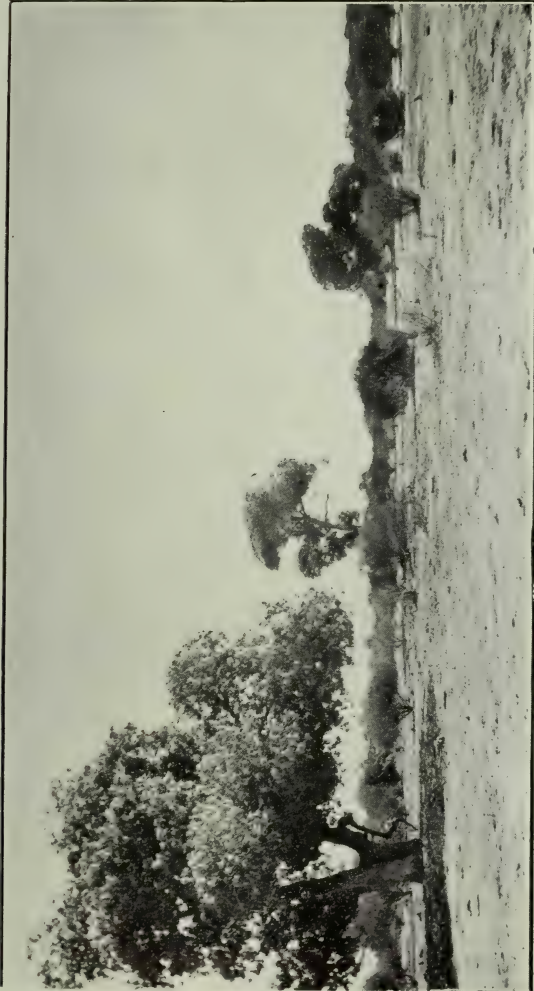


Photo., F. R. Feldtman.

F166.

Kurrajong Trees in granite country, about 2 miles S.W. of Res. 3092, Broad Arrow G.F.

About half-mile north of west from the above mine is the former King of Kings, G.M.L. 1150w, also in granite country. A large quartz reef on which a fair amount of work appeared to have been done was exposed in a small open-cut; a layer of greenish

brown micaceous schist on the walls of the reef was evidence that considerable shearing had taken place.

From this mine we proceeded to the Golden Coin G.M.L. 3048E—formerly the “Spin of the Coin,” about $1\frac{1}{4}$ miles north of west from the King of Kings. Here the dumps in places showed a distinctly aplitic phase of the granite. Some work was being done on the lease at the time.

The western boundary of the granite belt is only a short distance, probably about a quarter of a mile, to the west of this mine.

To the south of the 40-mile peg on the Broad Arrow-Kalgoorlie road the rocks are obscured by the Black Flag-Gordon chain of dry lakes. The writer had no opportunity of examining the country between them and the Six Mile, but it is possible that they mark the southern boundary of the granite belt.

GEOLOGICAL OBSERVATIONS IN THE MULLINE, RIVERINA, AND ULARRING MINING CENTRES.

I.—*General Remarks.*

The mining centre of Mulline is situated, as the crow flies, about 86 miles north-west of Kalgoorlie. The Riverina group of leases lies about $4\frac{1}{2}$ miles north-east of Mulline, whilst the Ullaring Centre is situated about the same distance south of Mulline. These centres form part of the Ullaring District, which also includes Mulwarrie, Davyhurst, and Mt. Ida, the whole being included in the North Coolgardie Goldfield.

The area covered by these notes is the northern portion of that described by Mr. C. G. Gibson in Bulletin No. 12 of the Survey, published in 1904.

From a glance at the Ore Value Diagram accompanying the present report (Plate XVII.), it can be seen that a good deal of work has been done since Mr. Gibson's survey of ten years ago. Unfortunately, our visit was of too hurried a nature to permit of much further mapping, and the accompanying geological map (Plate XV.) is that by Mr. Gibson, with a few additions by the writer. The classification of the rocks as shown in the legend, has been brought into harmony with the system at present in vogue.

The country within the limits of the map is, for the most part of an undulating character, with numerous rough ridges of greenstone, particularly at the northern end, west and north of Riverina, where they appear to form a rough crescent. A few of the hills are capped with laterite. South of Ullaring the country rises gradually to a long ridge of granite, bare in places, of which the Ullaring Rocks form the highest point. The vegetation of the granite consists chiefly of low mulga, with an occasional kurrajong. On the greenstone the timber is largely composed of morrell and gimlet gums, with a little sheoak on the ridges.

II.—*The Rocks.*

The rocks of the district may be classified as follows. —

- (1.) Amphibolites (including epidiorites and hornblende schists).
- (2.) Granite.
- (3.) Acid intrusives (dykes), including:—
 - (a) Granite-porphyry.
 - (b) Quartz-porphyry.
 - (c) Pegmatites.
- (4.) Basic intrusives (dykes)—Basaltic dolerite.
- (5.) Recent superficial deposits.
 - (a) Laterites.
 - (b) Sand, loam, etc.

(1.) *Amphibolites.*

The greater portion of the area described consists of these rocks, the Mulline township being situated near the centre of a roughly lens-shaped area of amphibolite, with a maximum width of about ten miles.

Fig. 20.



Photo., R. A. Farquharson.

Neg. 1205.

Microphotograph 13784.

The amphibolites, which were described by Gibson under the titles of "hornblende rocks" and "diorite" are composed chiefly of hornblende and felspar. The former mineral is seen

under the microscope* to occur as ragged fibrous plates and prisms with the interspaces occupied by small crystals of columnar labradorite felspar. Sphene and iron ores occur sparingly. The structure varies between gabbroid and ophitic. The colour of the rocks is a dark greenish gray, whilst the texture varies from medium coarse to fine grain, the latter being more common [13785]. One of the best examples of the coarser grained variety seen by the writer was at the former Day Dream G.M.L. 206v, where, in the hand specimen the rock appears to be chiefly composed of hornblende [13784] (Fig. 20). Other examples occur between Riverina and the group of hills to the west.

The amphibolites have been derived from gabbros or dolerites by alteration of the pyroxene to hornblende.

Along certain defined lines of shearing the amphibolites have been altered to hornblende schist, occurring, as a rule, in bands of only a few feet in width and usually surrounding the auriferous quartz reefs.

In places further alteration has resulted in the formation of biotite at the expense of some of the hornblende, by the introduction of potash [13786]. This is probably due to contact with acid intrusives, the biotitic rock, so far as the writer knows, occurring only in the vicinity of these rocks.

The amphibolites of this district probably correspond to the newer greenstone series of Kalgoorlie, but are much less altered than the rocks of the latter place, the intense shearing with subsequent chloritisation and carbonation over large areas being absent.

Like the corresponding Kalgoorlie rocks, the amphibolites form the country rock of most of the auriferous deposits.

(2.) *Granite.*

Surrounding the amphibolites, which appear in plan as irregular lenticular masses, are large areas of massive granite which, on the available evidence, is of later origin. But little granite occurs within the boundaries of the map (Plate XV.). It is best seen at the Ullaring Rocks, rather more than four miles south-south-east of the Ullaring centre. As already described, the Ullaring Rocks type is a normal medium grained biotite-microcline granite.

(3.) *Acid Intrusives.*

As can be seen from the map, these rocks are of frequent occurrence in the district and are found intruding the amphibolites. As a rule, their strike varies between north and south and north-west and south-east, with, in some cases, a westerly dip at a flat angle, in others, however, the dip is to the north-east, for example,

* NOTE.—The microscopical features of these and other rocks are from determinations by Mr. R. A. Farquharson, Petrologist to the Survey.

in the case of a granite-porphyry dyke near the former Mountain Daisy G.M.L. 312U. A few dykes with approximate east and west strike have been mapped by Mr. Gibson. The width varies from a few inches up to about sixty feet.

Fig. 21.

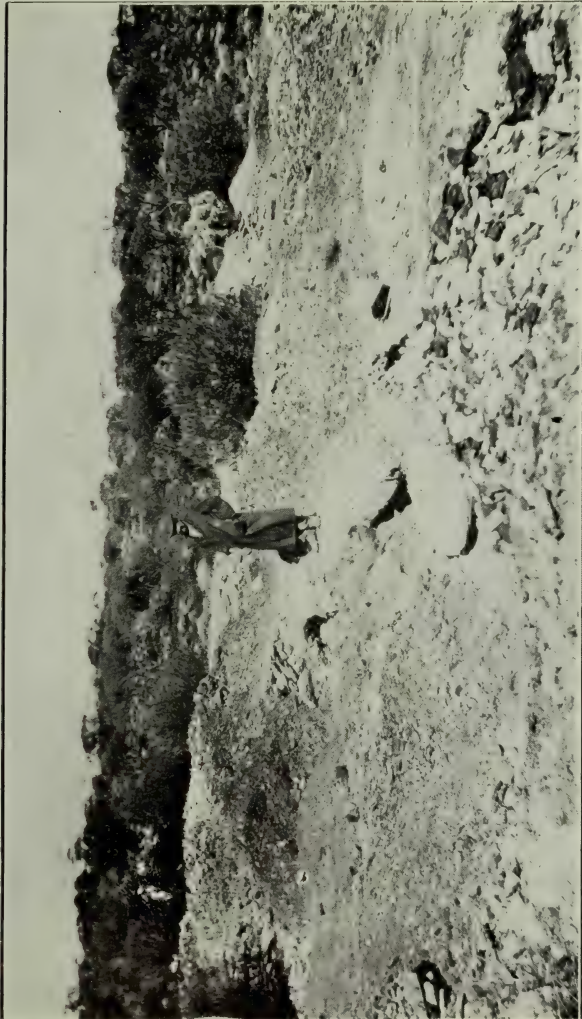


Photo., F. R. Feldtmann.

Neg. F146.

Former Mystery G.M. 548u, 3 miles S.W. of Mulline.
Showing Granite-Porphyry dyke intruding amphibolite.

These dykes may be divided into three main types, viz.:—

- (a) Granite-porphyry.
- (b) Quartz-porphyry.
- (c) Pegmatites.

(a) *Granite-porphyr.*

This type is not so common as the quartz-porphyr. It appears to occur in closer proximity to the main granite masses, which it resembles in general appearance, texture, and mineral composition, consisting of phenocrysts of quartz and felspar, largely microcline, but also acid plagioclase and some orthoclase, in a ground-mass of quartz and felspar; some biotite occurs and occasionally muscovite. The structure is intermediate between that of granite and of quartz-porphyr. These dykes are undoubtedly closely connected with the main granite masses, of which they are probably apophyses.

Fig. 22.

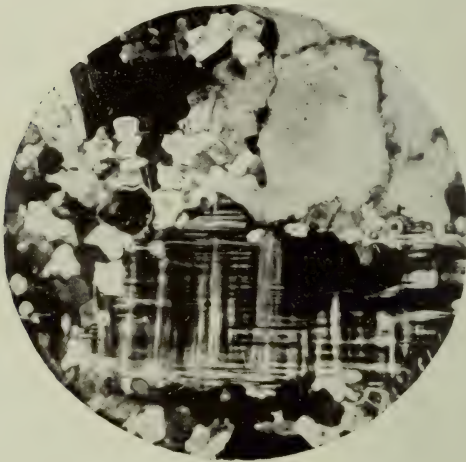


Photo., R. A. Farquharson.

Neg. 1206.

Microphotograph 13788.

Among the best examples seen by the writer was the occurrence at the former Mountain Daisy, already mentioned, where the dyke, which strikes approximately north-west and south-east, appeared to be about sixty feet in width.

The rock forming this dyke is of medium grain [13799], but coarser patches of pegmatitic character occur, with felspars up to an inch in length.

Some work had been done on this dyke, from which a little gold was said to have been obtained, probably from small quartz veins in the rock.

Another good example occurs on former G.M.L. 548u, Mystery [13788-9] (Fig. 21), where there are two of these dykes in fine grained amphibolite (Figs. 22 and 23), separated from each

other by about four feet of hornblende schist, somewhat micaceous in places, in which the auriferous quartz veins occur, sometimes contiguous to the dykes (Fig. 24). Here the strike is about 15 degrees west of north and the dip is to the east at about 30 degrees. One of the dykes is shown clearly on the accompanying photograph (Fig. 21). The dykes were about two feet in width; a few pegmatitic veins and patches were seen in them and some decomposed garnets were also observed. There was no alteration of the amphibolite at the contact, the junction being very clean [13787], (Fig. 26), showing that the dyke was near the point of consolidation when intruded into the amphibolite. Intruding both the dykes and the hornblende schist was a narrow dyke of basaltic dolerite, described later (Fig. 25).

(b) *Quartz-porphyry.*

These rocks are the commonest form of dyke in this district and were described by Gibson as "felsites." In the hand specimen they are almost white in colour and medium-fine to fine in grain. Phenocrysts of both quartz and feldspar are usually present, the former, however, being sometimes absent; the latter appears in

Fig. 23.

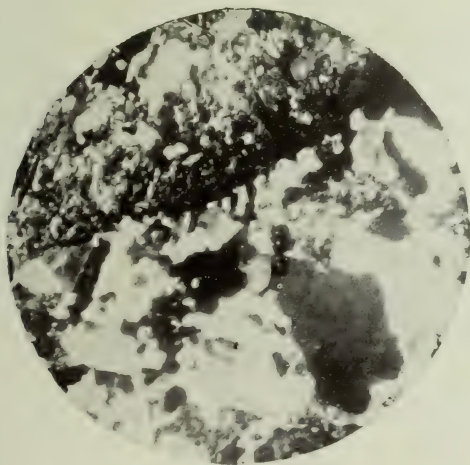


Photo., R. A. Farquharson.

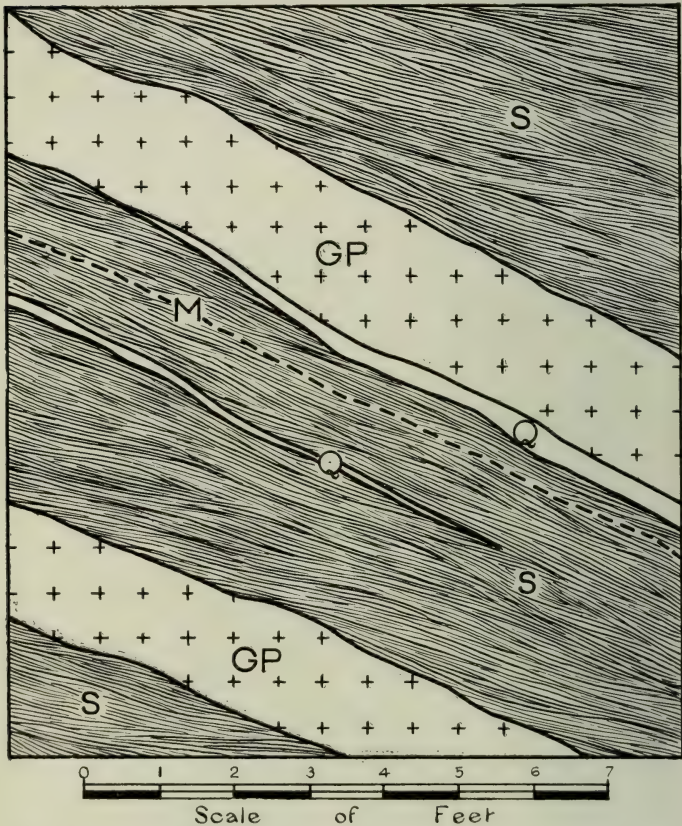
Neg. 1207.

Microphotograph 13787.

section to be in part orthoclase, in part acid plagioclase. The ground-mass is microcrystalline. A few nests of biotite, and occasionally a little muscovite, are to be seen.

At their contact with the amphibolite the quartz-porphyrries appear to be more felsitic in character and of flinty appearance, but phenocrysts can still be seen by the naked eye. Good examples both

Fig. 24.

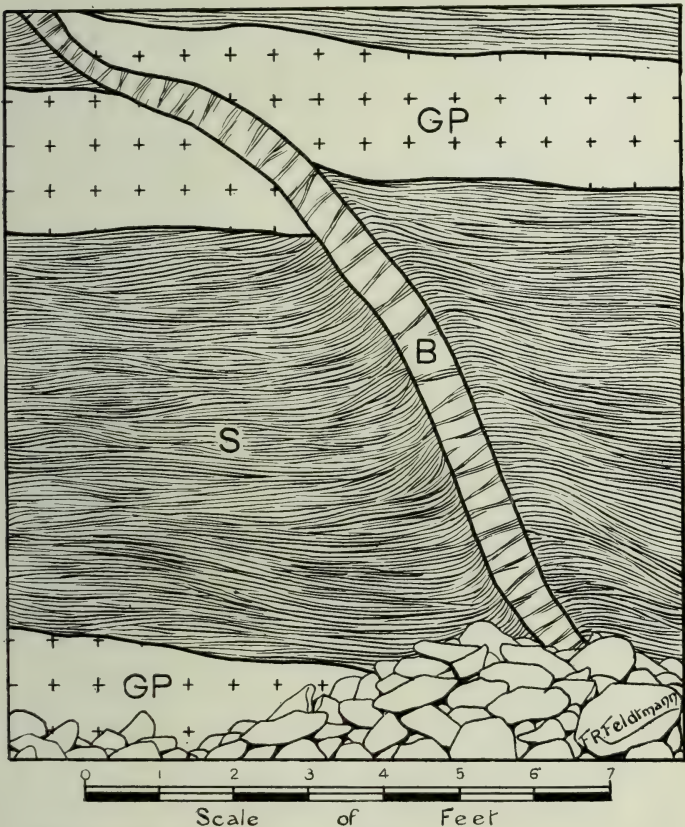


MYSTERY G.M., MULLINE. — Cross Section showing granite porphyry GP intruding amphibolite altered by shearing to hornblende schist S with quartz veins Q and "digs" of biotite M.

of the normal type and of the marginal felsitic variety were seen by the writer in the Cardinal G.M.L. 954u at Ularring [13794-5]. (Figs. 27 and 28). Another typical quartz-porphyry dyke was seen to the north-west of former G.M.L. 553u, Cora; in this instance the strike was about 17 deg. east of north. Some of these dykes show

a slight blocky structure, most easily seen in the weathered rock. Evidence of shearing with development of sericite along the shear planes is also present in some instances, whilst veins of yellowish resinous-looking quartz sometimes occur parallel to the shear planes. Some of these veins were being worked for their gold contents.

Fig. 25.



MYSTERY G.M., MULLINE — Section showing dyke of basalric dolerite **B** intruding granite porphyry **GP** and hornblende schist **S**.

Dyke rocks of similar type have been described by Mr. Woodward, Assistant Government Geologist, in his account of the auriferous deposits of Menzies.*

* G.S., W.A., Bulletin, No. 22, p. 16.

(c) Pegmatites.

Pegmatite dykes and veins are of fairly common occurrence. They vary greatly in size, some of the smaller veins seen by the

Fig. 26.

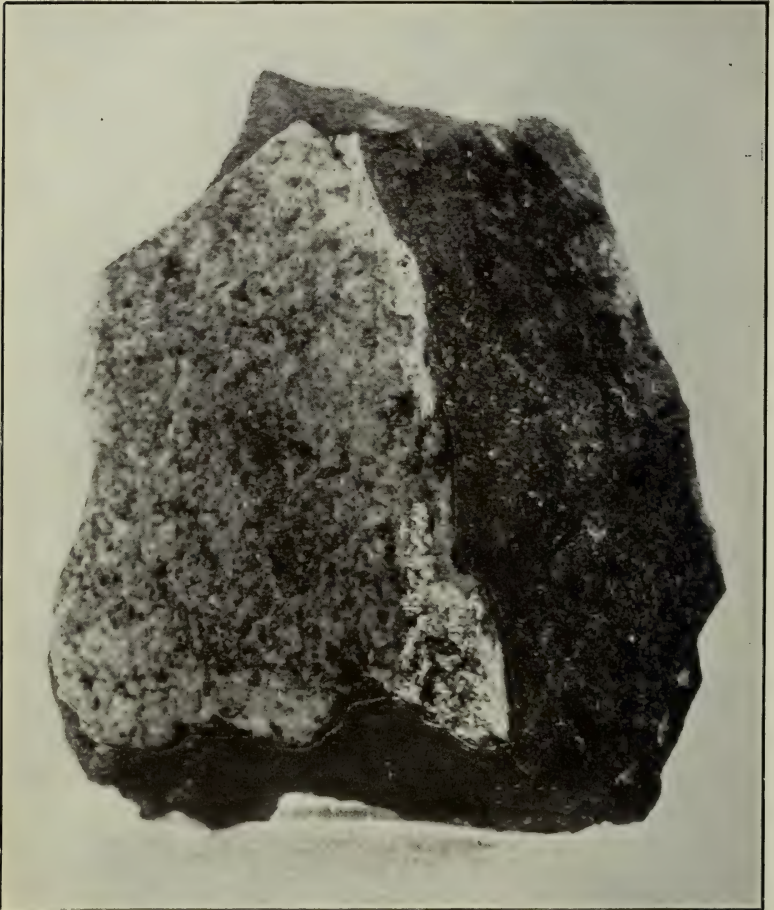


Photo., R. H. Irwin.

Neg. 1299.

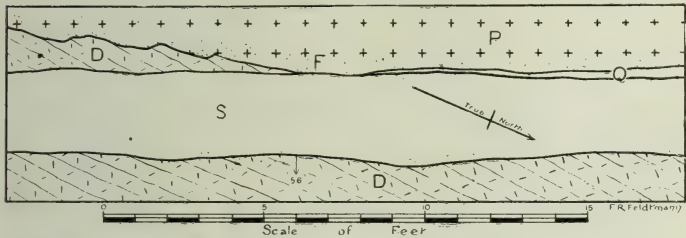
Specimen No. 13787, former Mystery G.M. 548u, Mulline.

Showing junction between Amphibolite and Granite-Porphry.

writer being only two or three inches in width and composed chiefly of felspar and quartz in greatly varying proportions, the ore vein consisting in places almost entirely of felspar [13801] passing into pure quartz within a distance of three or four feet. On the other

hand, much larger dykes occur, as large masses consist of quartz, felspars up to 8 inches in length by 2½ inches in width, and coarse nests of mica, were seen on the dump of the Riverina South main shaft, whilst several dykes about two feet thick and almost flat in dip were observed underground in the same mine.

Fig. 27.



CARDINAL G.M.L. 954u. ULARRING — Sketch Plan showing shear zone S (stoped), with auriferous quartz vein Q, in altered amphibolite D, and quartz porphyry P with felsitic margin F

Fig. 28.

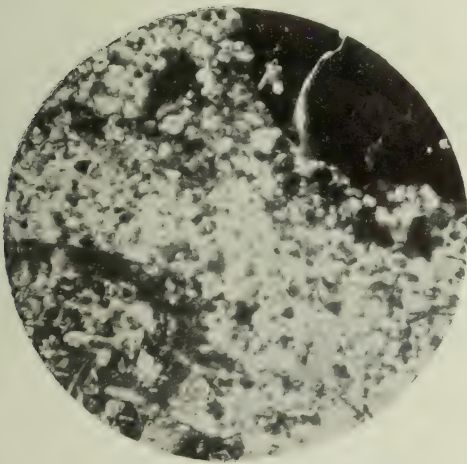


Photo., R. A. Farquharson.

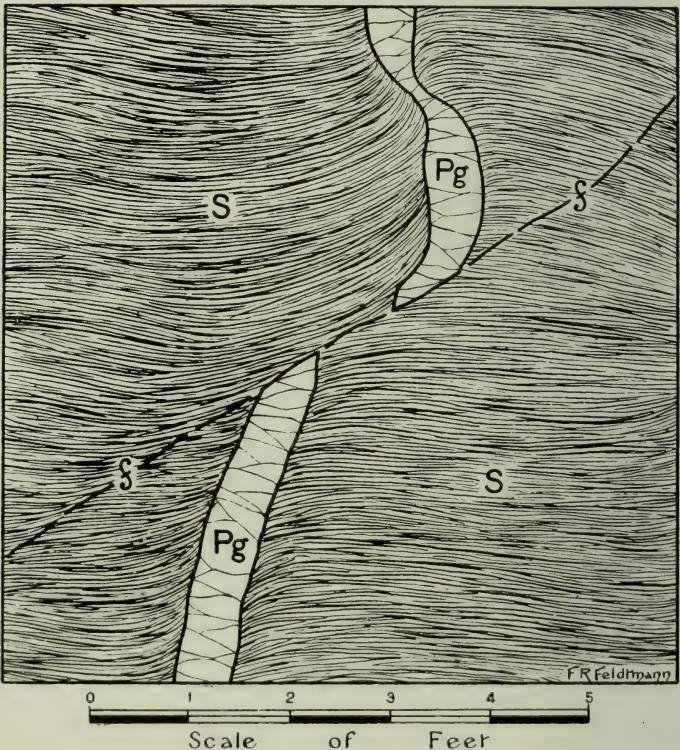
Neg. 1208.

Microphotograph 13794.

At the Riverina mine, north of the last named, a flat pegmatite vein about three inches thick is said to cut through and fault the ore body.

On former G.M.L. 961v. Golden Horn, at Hydenville, $2\frac{1}{2}$ miles north of west from Riverina, the quartz reef appears to have been cut by a nearly vertical pegmatite vein with resultant faulting of the former. Here the pegmatite consists chiefly of quartz and white mica with very little felspar. The strike of the pegmatite is nearly north and south with a slight dip to the west, whilst the quartz reef strikes about north-north-west and south-south-east with a north-easterly dip at about 40-45 degrees.

Fig. 29.



OFF CHANCE G.M., ULARRING — Overthrust faulting of cross vein of pegmatite Pg along fault plane § in shear zone of altered hornblende S

Other pegmatites were seen in the workings of the former Off Chance G.M.L. 766v, about three-quarters of a mile south-east of the Cardinal G.M. at Ularring. Here the strike was nearly east and west and more or less at right angles to that of the quartz

reef. One of these pegmatite veins, about eight inches thick and showing the sudden change in composition from almost pure feldspar to quartz, could be seen on the hanging wall of the ore body. This vein had been subjected to overthrust faulting (Fig. 29).

Fig. 30.



Photos, R. A. Farquharson.

Negs. 1209-10.

Microphotograph.

[5016]: (a) Microcline showing typical structure and albite intergrowths;

(b) Another view of the same.

On a dump at the former Chiltern G.M.L. 448U, numerous garnets up to one-third inch in size were observed associated with translucent epidote, also occurring in fair sized crystals, quartz and calcite, the larger garnet crystals being usually embedded in calcite. This occurrence is probably closely connected with a pegmatite dyke or vein.

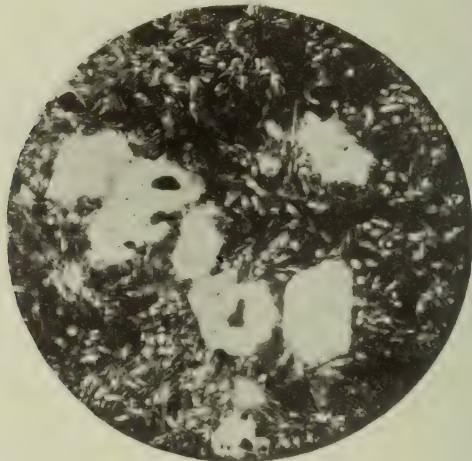
Of considerable interest is the occurrence of molybdenite in a specimen [5016] of pegmatite, obtained by Mr. Gibson, from G.M.L. 506U, formerly one of the Killaloe leases, at Mulwarrie. The molybdenite occurs as a few small specks in a white pegmatite of fairly coarse grain, composed of feldspar, largely microcline and albite, coarse crystals of clear quartz, and numerous books of greenish

brown muscovite. The microcline shows the characteristic cross-hatching most beautifully in section (Fig. 30). An additional feature of interest was the occurrence in this specimen of small purple crystals of fluorite, in one instance between the leaves of a mica "book." A few pale pink garnets were also present.

(4.) *Basic Intrusives.*

Only one example of this type was seen by the writer, viz:—In the shallower workings on the former Mystery G.M.L. 548c, previously mentioned in connection with the occurrence of granite-porphry dykes. Here the occurrence is in the form of a small dyke from three to six inches in width. The dyke appears to cut through both the hornblende schist and the granite-porphry, with, apparently, slight overthrust faulting (*vide* Fig. 25). It shows a marked prismatic jointing normal to its walls. The granite porphyry is apparently unaltered in the vicinity of this dyke. The rock is fine

Fig. 31.



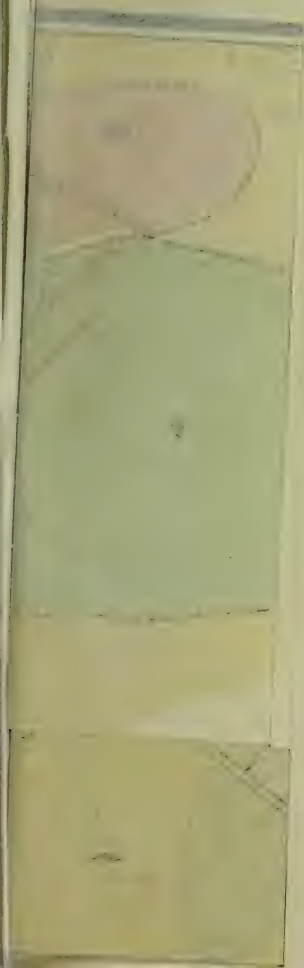
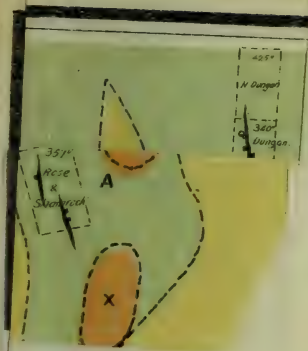
Microphotograph 13790.

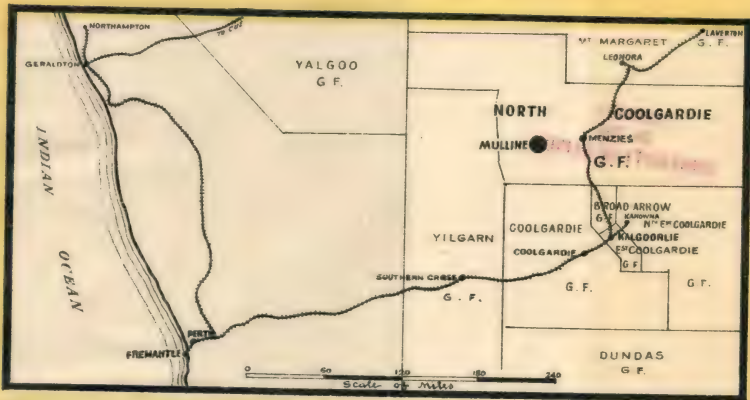
Photo., R. A. Farquharson.

Neg. 1211.

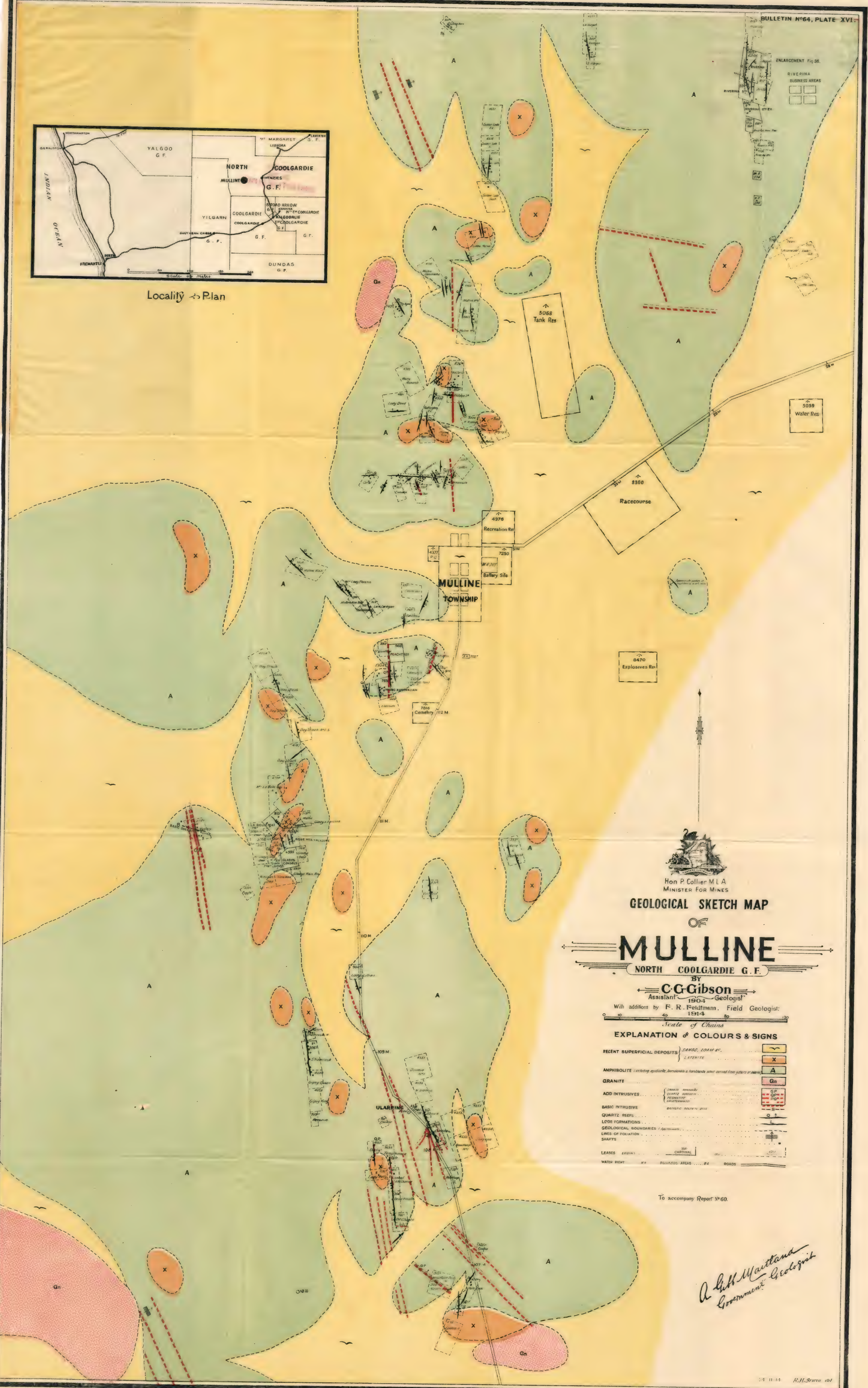
grained and of a dark grey colour with some small paler spots [13790] (Fig. 31). The Petrologist's description of the rock is as follows:—

In section, there are several clear, perfectly idiomorphic, hexagonal, square, rectangular and polygonal phenocrystal forms in a ground-mass that is made up of innumerable minute feldspar laths or needles forming a felted mass, in the interspaces of which are seen, with high powers, grains and apparent rods of almost isotropic yellowish-green chlorite representing probably original augite. A considerable amount of powdery brownish-black iron ore is associated with these chloritic scales amongst the feldspar. Yellowish-green chloritic patches occur in places in the slide and represent, doubtless,





Locality Plan



Hon P. Collier M.L.A.
MINISTER FOR MINES

GEOLOGICAL SKETCH MAP

OF

MULLINE

NORTH COOLGARDIE G.F.

BY
C. G. Gibson

Assistant Geologist

With additions by F. R. Feldtmann, Field Geologist:
1914

Scale of Chains

EXPLANATION OF COLOURS & SIGNS

RECENT SUPERFICIAL DEPOSITS	SANDS, LOAM, &c.	X
	LATERITE	A
AMPHIBOLITE	(including epidiorite, hornblende & hornblende gneiss derived from gneiss or diorite)	Gn
GRANITE		Gn
ACID INTRUSIVES	QUARTZ PORPHYRY DIORITE UNDISTURBED	GP DP BP
BASIC INTRUSIVE	BASALTIC DIORITE GNEISS	B
QUARTZ REEFS		Q
LODGE FORMATIONS		L
GEOLOGICAL BOUNDARIES	(dashed line)	- - -
LINE OF FOLIATION		— —
SHAFTS		+
LEASES	EXISTING	—
WATER RIGHT	—	—
ROADS		—

To accompany Report No. 60.

A. Pitt-Mann
Government Geologist

the original ferro-magnesian. The idiomorphic clear crystals as seen in section are composed in places of granular calcite often cracked across after the manner of olivine; and in other places, of a pale yellowish-green micaceous or chloritic substance in rather highly polarising scales. In form they appear once to have been felspar phenocrysts, but if so all the optical properties of felspar have disappeared. Some of those that contain calcite have the appearance of being formerly olivine. The structure of the rock appears to be porphyritic with a felted ground-mass of felspar laths or needles, between which grains of chlorite, doubtless representing former augite, are squeezed.

The rock is extremely weathered and much of its distinctive character has been obliterated. It appears, however, to be a much altered, somewhat porphyritic basaltic dolerite with resemblances to an augite andesite.

This dyke is the only example of this type seen by the writer on the eastern goldfields.

(5.) *Recent Superficial Deposits.*

(a) *Laterites.*—Laterite occurs on several of the hills in the district. The percentage of iron present varies somewhat. A highly ferruginous variety with pisolitic structure is to be seen on the south-eastern boundary of the Belle Maie G.M.L. 955U and the western portion of the adjoining Eady Gladys Junction, where the deposit has a thickness of about 16 feet. Much of the kaolinic material beneath the laterite has, in this instance, been stoped for its gold contents to a depth of 40 feet from the surface, the gold being evidently of a secondary nature and probably derived from the auriferous quartz veins in the vicinity. The value of the kaolinic material was said to vary from 5dwts. up to 35dwts.

A good example of the less ferruginous variety occurs on a low hill about two miles west of Riverina and beyond the main greenstone ridge. An abrupt escarpment forms part of the northern face of the hill (Fig. 32). A few small caves occur at the foot of the escarpment.

(b) *Sand, Loam, etc.*—The sand, gravel, loam and clay, forming the second type of recent deposits and covering the lower-lying ground, are of the usual kind found on the goldfields and need not be described here. There appears, however, to be but little of the travertine or "cement" so common at Kalgoorlie and others of the mining centres of the goldfields.

III.—*The Ore Deposits.*

The ore deposits may be briefly classified as follows:—

- (1) Primary, including:—
 - (a) Quartz reefs;
 - (b) Lode formations.
- (2) Secondary.

(1) *Primary Ore Deposits.*

(a) *Quartz reefs.*—Before dealing with the typical auriferous quartz reefs of this district, it is as well to mention another type of fairly common occurrence on the goldfields, namely, the large

white "buck" reef or quartz "blow," of which the reef near the 86-mile peg between Callion and Wangine Soak, and that at the latter place, are examples. These reefs are usually snow white in colour

Fig. 32.

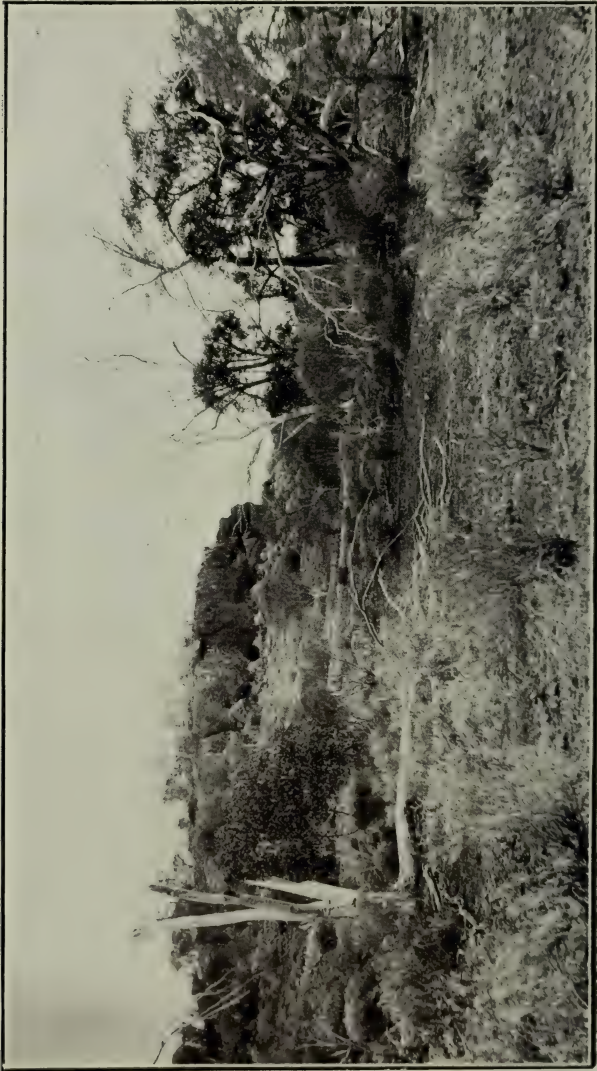


Photo., F. R. Feldtmann.

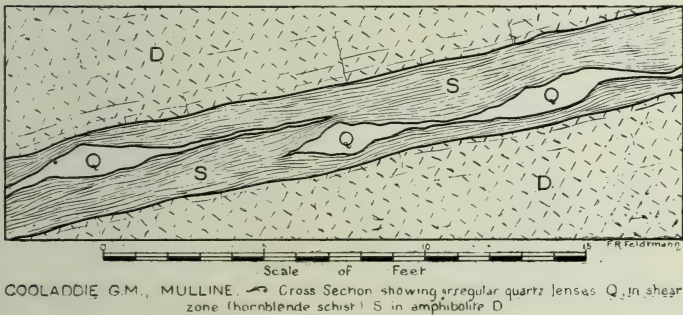
Laterite escarpment on Hill, 2m. W. of Riverina.

Neg. F145.

and are seldom found to carry gold. It is not improbable that they are related to the pegmatites and may be regarded rather as an

ultra-acid phase of the latter than as true reefs. At Mulline, reefs approaching this type are to be found in the former Cora, Himalaya, Day Dream, and Lady Florence leases. These are of considerable size, reaching about 10 feet in width in the Day Dream and 16 feet in places in the Lady Florence, the latter reef, which is iron stained at the surface, being situated about three chains east of the main auriferous reef on the mine. The strike varies from north-west and south-east to north-north-west and south-south-east. The Lady Florence and Day Dream reefs dip west, and the Cora and Himalaya reefs east.

Fig. 33.



The auriferous quartz reefs are the chief source of the gold obtained from this district. They closely resemble each other in size, general appearance and mode of occurrence, but vary considerably in strike and dip, those striking a few degrees west of north and east of south being apparently the commonest whilst the prevailing dip is to the east. In the Belle Maie the strike is practically north-west and south-east, whilst in the former Cooladdie and Victoria (former Mulline) mines the reefs strike east and west, with a southerly dip of about 10 degrees in the Cooladdie and a northerly dip of about 12 degrees, but varying somewhat, in the Victoria. Gibson mentions* that the east and west reefs are generally smaller and more irregular. A few of the reefs have a north-easterly strike, for instance, that on the former Commonwealth G.M.L. 467U; these dip to the south-east. In general the dip varies from 10 degrees in the Cooladdie to 60 degrees in the Cardinal. The Ularring reefs are steeper than those at Mulline, the former averaging between 50 and 60 degrees in dip, the latter probably between 20 and 30 degrees.

The reefs occur as irregular lenses of quartz of varying thickness, pinching and widening very rapidly, but seldom attaining a

* *Loc. cit.*, p. 12.

width of more than four feet as a maximum, in a zone of hornblende schist resulting from the shearing of the amphibolite (Fig. 33), the width of the shear zone, including the reef, being usually three or four feet. As previously mentioned there is frequently a development of biotite in the hornblende schist when in close proximity to an acid dyke, the biotite sometimes occurring as "digs" in the schist (*vide* Fig. 24).

The quartz lenses occur *en echelon* sometimes overlapping, but sometimes with a considerable space between each lens.

The values are said to be practically entirely in the quartz which is usually fairly glassy in appearance.

The mineral most commonly associated with the reefs is pyrite occurring sporadically in irregular, coarsely granular masses, usually on the walls of the quartz. The octahedral form appears to be most common, particularly in the larger crystals which reach two inches in size, but both the cube and the pyritohedron occur. The colour is greyer and less brassy than usual. The pyrite is said to carry no values. The best specimens obtained by the writer were from the dump of the Lady Florence; large bunches were also seen *in situ* in the Lady Gladys.

Galena, in small quantities, is fairly common. In the Cardinal mine it occurs, sometimes associated with free gold and a little quartz, in veinlets filling cracks in the amphibolitic rock roughly at right angles to and outside the main shear zone [13793]; the amphibolite here has been altered in places in the vicinity of the shear zone to a hornblende-epidote rock, somewhat banded [13792].

Zinc blende (sphalerite) is also found in small quantities in some of the mines.

Copper ores, chiefly malachite and azurite, were seen in small quantities on a dump at the Day Dream mine. A highly cupriferous quartz reef occurs about two miles east of Mulline. This reef is about four feet in width at the surface and has a north-west and south-east strike, dipping south-west. It contains the red oxide and both the green and the blue carbonates of copper, usually found filling joints and cracks in the quartz, from which prospects of gold up to 1oz. have been obtained. A picked sample of the ore, taken by Mr. Scully, who has done a little work on the reef, was said to have assayed 9.4 per cent. copper. The country rock is amphibolite of fairly coarse grain.

Epidote is fairly common as an alteration product in the shear zones near Ularring, but is not so noticeable at Mulline. In the oxidised zone it is frequently associated with veinlets of a pale waxy mineral, probably halloysite. This is of common occurrence in the former Off Chance G.M.L. 766v, Ularring.

Where dykes of quartz-porphyry are present, as in the Cardinal lease, the quartz reefs pass from one rock to the other, apparently undisturbed both in course and values.

In the Off Chance mine the shear zone is the most highly altered and by far the widest seen by the writer, reaching about 18 feet in places, and, as may be seen on the map (Plate XV.) is of considerable length. The shear zone appears to split going north,

Fig. 34.



Photo., F. R. Feldtmann.

Outcrop of Quartz Reef, former Derby G.M. 666U, Ularring.

Neg. F149.

with a horse of less altered country between the east and west arms. The auriferous quartz, which in this mine has a maximum width of

four feet, with an average of a few inches, some times pinching altogether, is usually found on the footwall side of the shear zone. The shearing appears to have been most intense along the hanging wall side, where, also, the greatest alteration has taken place, the rock, when somewhat weathered, presenting a curious spotted appearance, being of a greyish-green colour with pale yellowish patches and numerous small nests of brown biotite [13800]. It is seen in section to consist of a confused mass of plates and needles of hornblende partially chloritised, grains of sphene, nests of biotite and a little brownish chlorite, veinlets of a secondary mineral being also present. The rock has been derived by alteration and shearing from a hornblendite. The alteration is probably due to a great extent to the presence of dykes and veins of pegmatite which are common in the mine (*vide* Fig. 29).

Fig. 34 shows a fairly typical outcrop of an auriferous quartz reef.

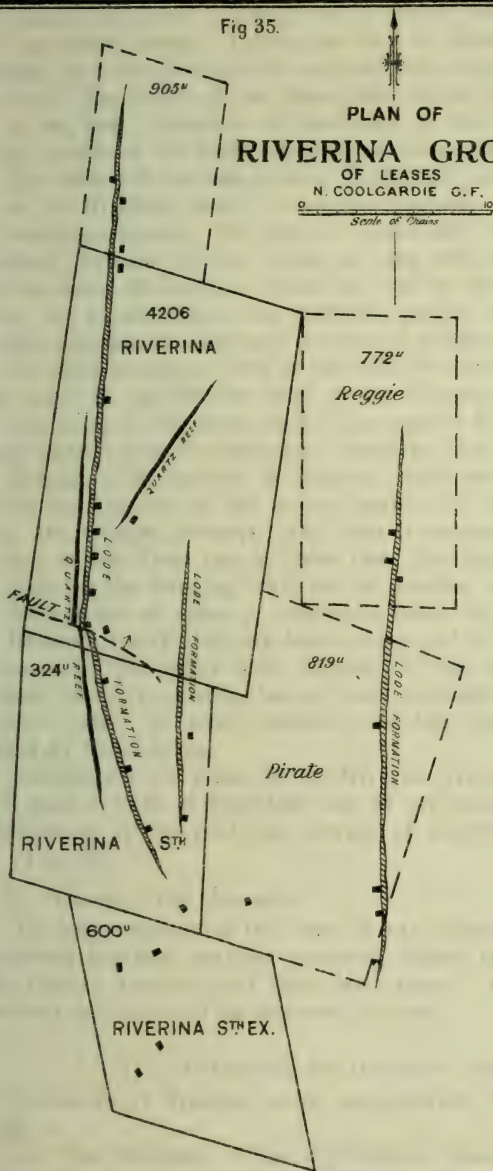
Among the mines most consistent as gold producers may be mentioned the Lady Gladys, Young Australian, Belle Maie, and former Cooladdie, Victoria (former Mulline) and Reprieve at Mulline, and the Cardinal (former Redleap), former Off Chance and Shamrock at Ularring. Returns for these and other mines up to the end of 1913 are shown in Appendix I. The total amount of ore mined from reefs of this type in the three centres being 63,489.92 tons for a return of 82,430.95 fine ozs.—an average of nearly 1.30 ozs. per ton.

(b) *Lode-formations*.—The main auriferous formations of the Riverina group may be classified under this heading. At first sight they appear to bear some resemblance to the lodes of Kalgoorlie, but on closer examination the resemblance is less marked, the most important differences being that the carbonation over extensive areas and the complete metasomatism of the zone of most intense shearing, characteristic of Kalgoorlie, are absent from the Riverina type. The main lode, running through the Riverina and Riverina South mines occupies a zone in the amphibolite which has undergone intense shearing with consequent mylonisation and re-crystallisation of the rock constituents, resulting in the formation of a banded rock [13779] seen in section to be composed of:—

“Imperfect bands of greenish blades of actinolitic hornblende with some sphene, granules, and plates of felspar with microcline structure, and mylonitic bands with which are associated colourless crushed plates apparently of a pyroxene and zoisite, with a little associated greenish hornblende, granules of sphene, and small, sometimes granulitised, plates of striped felspar (albite), and areas of sub-microscopic scales of a highly birefringent mineral resembling talc. Grains of pyrrhotite are also present.”

Nearer the walls of the crushed zone the banding is coarser and less perfect [13778]; the blades of hornblende are very much coarser and in section a fair amount of biotite is present.

Fig 35.





Pyrrhotite, in addition to ordinary pyrite, is disseminated in small quantities throughout the shear zone; small patches of galena and blende also occur, showing that a certain amount of impregnation has taken place. Values are said to follow the pyrite, and probably both the gold and the sulphur were introduced by the same solutions. The width of the shear zone varies from about two feet up to ten feet. Evidence of movement in the form of striæ is plainly visible on the walls, the striæ dipping to the north.

The strike of the lode is about north and south in the Riverina, but in the Riverina South it changes gradually to north-north-west and south-south-east. The lode is practically vertical. Near the boundary between the two mines an east and west fault, dipping north at about 40 degrees, throws the lode 29 feet to the west going north. By a coincidence the northern portion of the lode is thus brought opposite the southern portion of a white quartz reef which lies the same number of feet to the west of and runs parallel to the main lode. At the 200-foot level on the Riverina the fault is about 110 feet south of the main shaft. It is marked by a band of whitish puggy matter, possibly halloysite, about an inch thick.

Owing to the amount of stoping which had been done a systematic examination of the central portion of the lode was impossible. Mr. Gibson, however, says* that it consisted of white quartz varying in size from one to three feet; the quartz being found at one time on the hanging wall and at another on the foot wall.

Flat dykes or veins of pegmatite occur in both mines, but in the Riverina South they are both larger and of more frequent occurrence. In the latter mine portions of the ore-body are found enclosed in the pegmatite, having been probably caught up by the intrusive mass. In some instances the lode has apparently been faulted by these dykes.

Returns for the mines of the Riverina group up to the end of 1913 show a total of 33,632.50 tons of ore mined for a return of 22,355.39ozs. of fine gold—an average of slightly over 0.66ozs. per ton (Fig. 35).

(2) *Secondary Ore Deposits.*

The only example of this class of any importance is that of the auriferous kaolinic material occurring under the laterite in the Lady Gladys Junction and Belle Maie leases. It has already been described and need not be discussed further.

IV.—EVIDENCES OF DYNAMIC ACTION.

Evidences of dynamic action are plentiful, the most important being:—

(a) The shearing of the amphibolite along well-defined lines with resultant formation of hornblende schist, thereby making a path for the auriferous solutions;

* *Loc. cit.*, p. 12.

(b) The mylonisation of the country rock along the Riverina line of lode; and

(c) The numerous subsequent faults of which, perhaps, that previously mentioned as affecting the Riverina line of lode is one of the most important; other minor faults are found—for example, those mentioned by Gibson* as affecting the Mulline reef; the faulting of several of the reefs by pegmatite veins or dykes, and, further, the faulting of one of the latter in the Off Chance mine, and the apparent faulting of a granite porphyry dyke by a small greenstone dyke in the Mystery.

From these examples it would appear that dynamic action has taken place over a considerable period of time, and, with the exception of (b), the shearing and faulting is probably largely the result of stresses set up by the intrusion of the acid rocks.

V.—RELATIVE AGES OF THE ROCKS AND THEIR RELATIONSHIP TO EACH OTHER AND TO THE ORE DEPOSITS.

All the available evidence found on the Eastern Goldfields points to the fact that the large granite masses are later than, and intrusive into the greenstones, of which, as previously stated, the amphibolitic rocks of the Ullaring District probably correspond to the newer greenstone series of Kalgoorlie.

The proximity of the granite-porphyry dykes to the main granite masses and their close resemblance to the latter in appearance and mineral composition point to the conclusion that the former are apophyses from the latter intruded into the surrounding amphibolite.

The quartz-porphyry is undoubtedly intrusive into the amphibolite, but there is no evidence as to its relationship to the granite and the granite-porphyry.

Both the quartz and granite-porphyries appear to be older than the auriferous quartz reefs, which, in many instances, possess similar strike and dip to them. The junctions between these porphyries and the amphibolites probably formed important lines of weakness—though not the only ones—affected by dynamic stresses prior to the introduction of the gold, the amphibolite being the more easily affected, so that the auriferous reefs are more usually found in it, occurring sometimes in the quartz porphyries as well, as shown by examples already mentioned, in addition to which is the occurrence, mentioned by Gibson,† at the Thunderbolt mine at Mulwarrie, of a large felsite (quartz-porphyry?) dyke, in which, besides an irregular quartz vein on the hanging wall of the dyke, innumerable quartz stringers carrying gold were said to form a large stockwork.

* *Loc. cit.*, p. 14.

† *Loc. cit.*, p. 21.

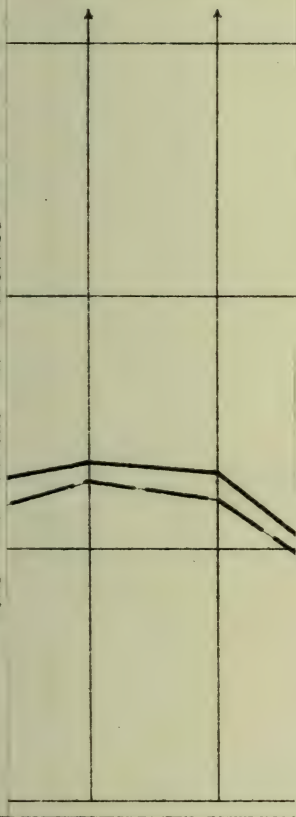
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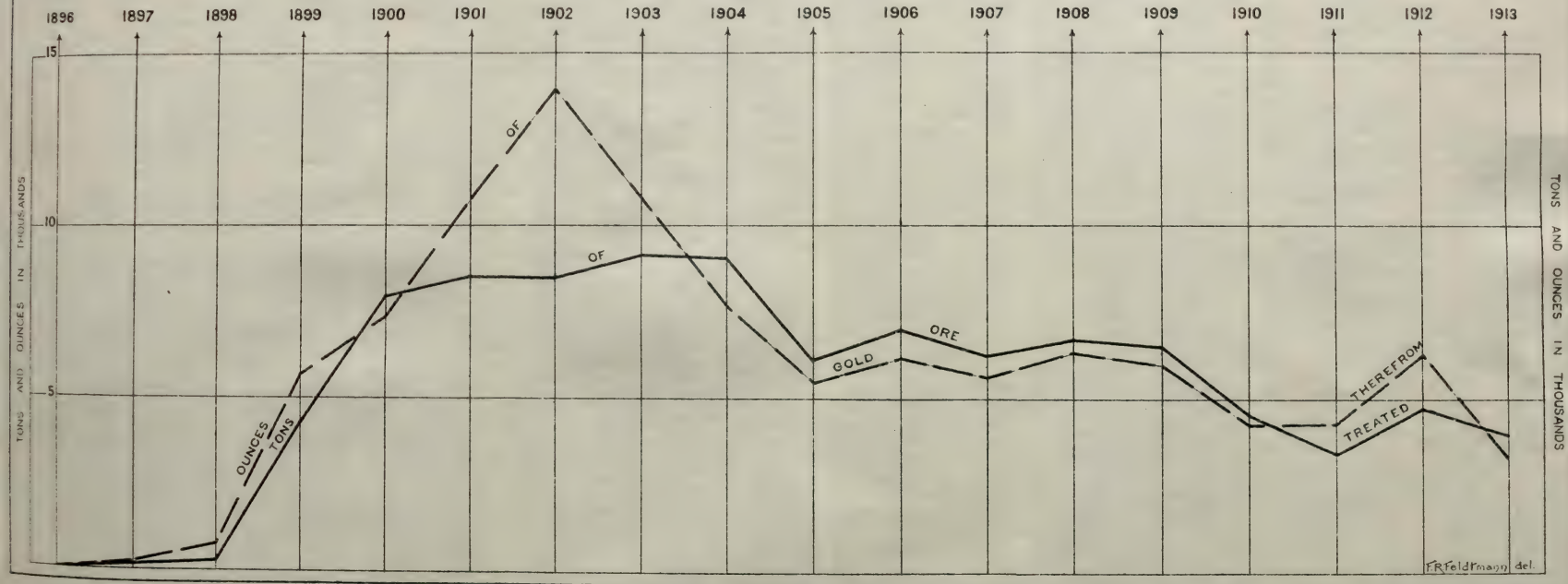
A. GIBB MAITLAND
GOVERNMENT GEOLOGIST

BULLETIN N°64 PLATE XVII

ORE VALUE DIAGRAM

OF MULLINE, RIVERINA AND ULARRING CENTRES

Shewing Tons of Ore treated and Ounces of Gold therefrom for each year since 1896.



FReldmang del.

H. J. Pether, Government Lithographer, Perth, W.A.

Some, at least, of the pegmatites appear to be later than the quartz reefs, and therefore later than the other acid intrusives.

The small greenstone dyke on the Mystery is apparently later than both the quartz reefs and the granite-porphry.

The district affords some interesting evidence as to the original source of the gold, particularly with regard to the suggestion put forward by some writers that gold was an original constituent of the gabbroid or doleritic rocks from which the amphibolites forming the country rock of auriferous reefs and lodes have been derived by uralitisation. It was suggested that the gold was held in combination by the ferro-magnesian minerals, the later splitting up of these into chlorite, etc. facilitating the dissolving of the gold by solutions with subsequent deposition along the main lines of weakness. Now chloritisation or other alteration of the hornblende, other than that due to surface weathering, is practically negligible in the Ularring district. It certainly does not occur on a sufficiently large scale to have resulted in the setting free of gold in such quantities as have been obtained from the mines of the district. So that in this district, at any rate, we must look to some other source for the gold, and, in the writer's opinion, the available evidence appears to point to a close connection between the introduction of the gold-bearing solutions and the intrusion of the acid dykes into the amphibolites, both, in all probability, being products of the same magma.

APPENDIX I.

MULLINE CENTRE (INCLUDING RIVERINA).

Total Returns for Voided Leases.

No. of Lease.	Name.	Date when Lease was cancelled.	Ore treated.	Gold there- from.
			tons.	fine ozs.
327U ..	Acrobat	13-10-99	55·67	79·49
501U ..	Ajax	4-7-02	257·75	263·31
74U ..	Albury	13-10-99	25·00	59·85
243U ..	Anastasia	14-10-98	19·00	42·80
552U, (243U)	do.	7-6-00	20·00	8·87
450U, (357U)	Argentina	9-8-01	148·00	59·35
179U ..	Belle Maie	23-7-09	3,457·00	3,641·67
916U ..	do.	30-6-11	286·50	160·02
446U ..	Boer	31-3-00	11·00	4·34
162U ..	British Lion	14-3-02	63·80	72·72
949U ..	California	21-2-13	22·00	25·76
448U ..	Chiltern	9-8-01	34·50	16·55
918U ..	Claymore	28-1-10	12·00	20·06
917U ..	Clingstone	8-7-10	42·50	76·75
433U ..	Cocas	18-1-00	34·50	40·39
601U ..	Comet	4-7-02	72·00	56·96
330U, 408U	Cooladdie	1-6-06	3,836·50	4,826·87
840U, (330U, 408U)	do.	22-10-08	683·50	329·84
553U ..	Cora	4-7-02	36·25	124·62
943U ..	Corona	4-4-12	13·50	11·67
362U ..	Dawn	13-10-99	30·00	18·13
206U ..	Day Dream	13-10-99	10·00	1·95
314U ..	Day Dream S. No. 2 Ex.	9-8-01	81·00	85·85
688U ..	Dismissal	18-8-02	22·00	12·09
353U ..	Don Juan	28-7-99	72·50	70·94
603U ..	Duchess of York	17-7-03	134·00	70·47
779U ..	do.	14-7-05	45·00	20·34
340U ..	Dungan	4-7-02	156·50	93·05
941U ..	Elsie	4-4-12	48·00	83·75
922U ..	Evening Star	8-7-10	17·50	42·05
542U ..	Exchange	21-11-00	7·00	10·21
761U ..	George Frederick	14-7-05	17·50	14·12
807U ..	Gladstone	30-11-06	141·00	198·83
871U ..	Golden Horn	5-7-12	409·00	742·87
350U ..	Golden Lode	13-10-99	13·50	20·98
936U ..	Golden Rock	5-7-12	244·00	466·11
315U ..	Gold Standard	13-10-99	168·00	134·22
435U, (315U)	do.	17-8-00	80·00	95·13
483U, (385U)	Great Expectation	10-5-01	55·00	8·60
894U ..	Great Leviathan	30-6-11	199·00	431·22
940U ..	Guy	5-7-12	61·00	45·28
762U ..	Himalaya	3-8-06	232·00	69·87
765U ..	Hit or Miss	14-7-05	67·50	17·52
934U ..	Home Turn	7-3-13	117·50	126·62

APPENDIX I.—*continued.*

No. of Lease.	Name.	Date when Lease was cancelled.	Ore treated.	Gold therefrom.
			tons.	fine ozs.
635U ..	Hornet's Nest	4-7-02	3.50	6.90
921U ..	Jack	21-1-10	13.50	5.57
575U ..	Karrakatta	4-7-02	12.00	80.23
769U ..	Keep it Dark	14-3-04	10.00	5.92
403U ..	Lady Florence	22-7-04	1,084.00	534.65
785U ..	do.	3-2-05	6.00	7.45
290U ..	Lady Gladys Junction ..	11-12-97	902.00	715.10
670U ..	Lady Gladys Junction (transferred to Lady Gladys G.M.Co., N.L., 26-8-03)	7-12-13	..	52.78
534U ..	Le Grande	9-8-01	7.00	5.73
752U ..	Little Gem	3-8-06	10.00	2.70
328U ..	Marvellous West	13-10-99	158.00	148.62
719U ..	Melba	22-7-07	9.00	7.80
528U ..	Mikado	9-8-01	19.00	18.46
451U, (45U)	Monarch	9-8-01	79.00	45.25
95U ..	Golden Wonder (Mon- arch G.M. Co., N.L.)	19-1-00	311.00	290.54
892U ..	Mt. Woolhouse	30-6-11	159.00	182.33
2U ..	Mulline	14-7-05	1,664.25	1,980.40
2U, 282U ..	Mulline Leases	1-8-05	258.00	177.46
		(282U) amal- gamated with 282U, 18-9-02		
704U ..	Mulline Commonwealth	22-5-03	51.00	24.48
895U ..	Mulline Gift	16-4-09	60.00	153.53
595U ..	Mulline Rose	4-7-02	31.50	16.11
710U ..	Mulline Surprise	20-1-03	17.50	19.71
437U ..	Mystery	9-11-00	153.00	122.71
548U, (437U)	do.	29-11-01	137.00	130.38
409U ..	New Find	4-11-99	25.00	184.74
434U, (328U)	Nil Desperandum	21-8-03	646.75	779.38
311U ..	Our Luck	13-10-99	50.00	55.55
839U ..	Overlander	15-3-07	27.00	26.97
356U ..	Perseverance	13-10-99	8.00	7.39
819U ..	Pirate	26-7-07	384.50	255.74
444U ..	Pride of the Hills	13-10-00	41.00	48.64
923U ..	Prodigal	8-7-10	50.50	49.17
583U ..	Queen Mary	20-6-01	45.50	12.57
758U ..	Recovered Rights	25-11-04	54.50	22.04
423U ..	Refuse	9-8-01	58.00	44.96
772U ..	Reggie	14-7-05	100.00	55.98
716U ..	Reprieve	21-8-03	28.00	48.94
422U, 462U	Reprieve leases	4-7-02	727.50	1,488.75
810U ..	Riverina Main Reef	11-10-7	413.00	170.78
784U ..	Riverina North	30-6-05	77.75	52.17
390U ..	Riverina N. Ex.	11-12-99	33.00	67.80
359U ..	Riverina No. 1 N.	17-8-00	128.00	76.77

APPENDIX I.—*continued.*

No. of Lease.	Name.	Date when Lease was cancelled.	Ore treated.	Gold there- from.
			tons.	fine ozs.
545U ..	Riverina Perseverance ..	17-7-03	106·00	72·57
794U ..	Riverina Star	3-8-06	74·75	27·50
357U ..	Rose and Shamrock ..	13-10-99	121·00	61·59
497U ..	Schnider	15-1-01	18·00	12·29
836U ..	Standard	1-3-07	62·00	41·73
889U ..	Tasmanian	17-7-08	9·00	4·94
705U, (390U)	Three Gins	17-7-03	24·50	69·28
367U ..	Try Again	17-8-00	200·75	180·94
385U ..	Vera	13-10-99	20·50	27·82
571U ..	Victoria	4-7-02	62·00	86·73
826U ..	do.	26-7-07	377·00	278·85
397U ..	Victoria Extended ..	6-4-01	47·00	113·23
345U ..	Victorian	17-8-00	106·50	213·80
853U ..	Victoria South	25-9-08	16·50	8·66
800U ..	Victory	3-8-06	72·00	32·01
661U ..	Waratah	29-8-02	7·00	3·00
708U, (345U)	Yankee Doodle	17-7-03	29·00	12·10
332U ..	Young Australian ..	25-7-02	150·00	341·05
699U, (332U)	do.	15-5-03	39·25	22·59
703U, (332U)	Young Australian E. ..	17-7-03	23·50	12·95
910U ..	Young Australian N. ..	5-7-12	24·50	22·32
790U ..	Young Boulder	24-8-06	51·00	15·68

ULARRING CENTRE.

Total Returns for Voided Leases.

No. of Lease.	Name.	Date when Lease was cancelled.	Ore treated.	Gold there- from.
			tons.	fine ozs.
692U ..	Block 45	20-9-02	6·00	2·17
900U ..	Cardinal	30-6-11	808·00	2,082·83
351U ..	Central Off Chance ..	31-8-00	11·00	1·64
911U ..	Clinker	12-8-10	42·50	33·41
348U ..	Cuba	13-10-99	4·00	12·25
373U ..	Daimio No. 2	26-7-01	97·50	135·34
754U ..	Dead Finish	29-6-06	281·25	308·13
339U ..	Derby	9-8-01	163·25	133·66
666U, (339U)	do.	17-7-03	119·25	185·59
780U ..	Drusilla	26-7-07	180·00	357·19
376U ..	Lady Betty	13-10-99	10·00	4·56
904U ..	Lady Lillian	13-8-09	38·00	22·30
346U ..	Matchless	27-7-99	8·00	2·84
338U ..	Off Chance	17-4-03	1,272·00	2,243·15
776U ..	do.	21-5-09	889·50	1,147·27
370U ..	Puzzle	22-4-99	37·00	26·76
92U ..	Redleap Ext. Explorers, Ltd.	26-7-07	2,342·10	4,042·24
759U ..	Revenue	25-2-04	7·50	5·56
1U ..	Shamrock	14-7-05	1,690·75	2 097·00
888U ..	do.	30-6-11	799·50	605·49
371U ..	Shamrock North ..	13-10-99	38·00	26·28
360U ..	Trio	17-8-00	88·75	95·55
406U ..	Yale Lock	17-8-00	30·00	6·28

MULLINE CENTRE (INCLUDING RIVERINA).

Total Returns for Leases existing in 1913.

No. of Lease.	Name.	Ore treated.	Gold therefrom.
		tons.	fine ozs.
955U	Belle Maie	27·75	86·27
957U	Crusoe	33·00	5·89
958U	Gladiola	4·00	5·07
961U	Golden Horn	23·50	41·64
139U, 235U, 555U ..	Lady Gladys leases ..	7,741·00	15,195·94
139U, 235U, 555U, 670U, and voided leases	Lady Gladys G.M. Co., N.L.	16,871·50	17,777·42
671U, 677U, 679U, 685U, 709U, 727U, 732U, 774U, 775U, 776U, 862U			
139U, 235U, 555U, 670U	do. do.	1,220·50	512·52
Do. do.	Lady Gladys leases ..	371·50	169·55
872U (voided 11-4-13)	Peach Tree	292·50	354·92
960U	do.	28·25	30·07
123U, 162U, 683U, 773U, 829U	Riverina G.M. Co., N.L.	11,254·00	7,096·21
123U	Riverina	5,657·00	3,012·82
324U, 600U, 730U ..	Riverina South leases	15,394·50	11,464·35
763U	Young Australian ..	1,295·00	3,609·26
763U, 938U, 939U ..	Young Australian leases	2,487·75	5,534·88
	Sundry Claims ..	3,921·25	3,484·28

ULARRING CENTRE.

Total Returns for Leases existing in 1913.

No. of Lease.	Name.	Ore treated.	Gold therefrom.
		tons.	fine ozs.
954U	Cardinal	73·00	70·30
	Sundry Claims ..	143·00	113·15

Grand Totals for Mulline, Riverina, and Ularring Centres, up to end of 1913—Tons 97,122·42, fine ozs. 104,786·34 ; being at the rate of 1·08 fine ozs. per ton.

23rd November, 1914.

INDEX.

	Page
Acid Intrusives	134
Acid Rocks	18
Acrobat lease	154
Ajax lease	154
Albury lease	154
Alluvial Deposits	27
<i>Ammonites</i>	88
<i>Do.</i> <i>Championensis</i>	87
Amphibolites	133
Anastasia lease	154
Aplite	19
Argentina lease	154
Ashburton Goldfield	97, 98
<i>Athyris capillata</i>	87
<i>Do.</i> <i>Macleayana</i>	87
<i>Aucella Hughendensis</i>	88
<i>Aulosteges Baracoodensis</i>	87
<i>Do.</i> <i>Medlicottianus</i>	87
Aurum lease	48
<i>Ariculopecten tenuicollis</i>	86
Bardoc	107, 108, 110
Bardoc Belt	107
Basic Intrusives	144
Basic Rocks	15
Belle Maie lease	145, 147, 150, 151, 154, 158
Blatchford, T.	128
Block 45 lease	157
Boer lease	154
Bonnie Venture Group	49
Brachiopods	88
British Lion lease	154
Broad Arrow	107, 108, 126
Brown, H. Y. L.	80
Bulimina	9
California lease	154
Callie Soak	55
Callion	111
Cambrian Rocks	84
Canegrass	108, 111
Carboniferous Rocks	85
Cardinal lease	138, 141, 148, 150, 157, 158
<i>Cardium</i>	89
Catherine Range	14, 16, 19, 20, 21, 38
Central East lease	39
Central Off Chance lease	157
Chapman, F.	8
Chiltern lease	143, 154
Chloritoid	64-69, 71-78
Christmas leases	122
Claymore lease	154
Clingstone lease	154
Clinker lease	157
Clintonite Group	64

INDEX—continued.

	Page
Coal Fields	7-12, 104, 105
Cocas lease	154
<i>Coelosmitia</i>	88
Colie Coal, Age of	9
Do, Chemical Composition of	10
Collie Coalfield	7-11, 104, 105
Comet lease	154
Commonwealth lease	147
Concentration Tests	24
Cooladdie lease	147, 150, 154
Copper Fields	103
Cora lease	138, 147, 154
Corona lease	154
Cretaceous Rocks	87
Crusoe Group	50
Crusoe lease	158
Cuba lease	157
Daimio No. 2 lease	157
Daisy lease	24, 25, 38
Davyhurst	108, 118
Davyhurst-Mulline Belt	108, 112
Dawn lease	154
Day Dream lease	147, 154
Day Dream South No. 2 Extended lease	154
Dead Finish lease	157
Derby lease	157
Devonian Rocks	85
Dismissal lease	154
Don Juan lease	154
Double Birthday Gift lease	129
Drusilla lease	157
Duchess of York lease	154
Dungan lease	154
East Coolgardie Goldfield	101-103
Eastern Goldfields	100-103
Elsie lease	154
<i>Endothyra</i>	9
<i>Euomphalus</i>	86
Evening Star lease	154
Exchange lease	154
Felsite	21
<i>Fissilunula</i>	88
Foraminifera	8, 9
Gascoyne Goldfield	97, 98
Gastropod	88
George Frederick lease	154
Gibson, C. G.	132
Gladiola lease	158
Gladstone lease	154
<i>Glossopteris</i>	8, 9
Do, <i>angustifolia</i>	9
Do, <i>browniana</i>	9
Do, <i>gangamopteroides</i>	9
Do, <i>indica</i>	9

INDEX—continued.

	Page
Golden Coin lease	132
Golden Eagle Group	46
Golden Horn lease	142, 154, 158
Golden Lode lease	154
Golden Rock lease	154
Golden Wonder lease	155
Gold Standard lease	155
<i>Goniatites</i>	86
Gordon	107-109
Granite	19, 108, 134
Great Expectation lease	154
Great Leviathan lease	154
Greenbushes Tinfield	104
Greenstones	107
Gregory, F. T.	85, 87
Guy lease	154
 Hardman, E. T.	80, 85
Hayes Consols lease	129
Hidden Treasure lease	129
Himalaya lease	147, 154
Hit or Miss lease	129, 130, 154
Home Turn lease	154
Hornet's Nest lease	155
 <i>Inoceramus</i>	88, 89
Ironclad lease	48
 Jack lease	155
Jurassic Rocks	87
 Kalgoorlie Rocks, Classification of	52
Kanowna-Mulgarrie Belt	107
Karrakatta lease	155
Keep-it-Dark lease	155
Kilialos leases	143
Kimberley	11, 80, 94
King of Kings lease	131
King of the South lease	37
King of the West lease	130
 Lady Ailsa lease (<i>see</i> Melba lease)	
Lady Betty lease	157
Lady Florence lease	147, 148, 155
Lady Gladys G.M. Co., N.I.	158
Lady Gladys Junction lease	145, 151, 155
Lady Gladys leases	148, 150, 158
Lady Lillian lease	157
Lake Raeside	15, 17, 18, 22, 44
Laterite	22, 89, 145
LeGrande lease	155
Little Gem lease	155
Lower Livinga Station	11
<i>Loxonema</i>	86
Lyons Conglomerate	86
 <i>MacCoyella Corbiensis</i>	88
<i>Magellania</i>	89

INDEX—continued.

	Page
Maitland, A. Gibb	14, 18
Marvellous West lease	155
Masonite	64
Matchless lease	157
Melba lease, Mulline	155
Melba lease, Yerilla	23-26, 34, 35, 41
Mesozoic Rocks	79
Mikado lease	155
Molybdenite	25, 55, 143
Monarch lease	155
Montgomery, A.	14, 34, 37, 38, 40
Mountain Daisy lease	135, 136
Mt. Catherine	15, 20, 21, 23, 25, 37, 38
Mt. Cay	15
Mt. Gibson	50
Mt. Malcolm Copper Mine	103
Mt. Singleton	49
Mt. Woolhouse lease	155
Mugs Luck lease	48
Mulgarrie	107, 109, 128-130
Mulline	108, 132
Mulline Commonwealth lease	155
Mulline Gift lease	155
Mulline leases	155
Mulline Rose lease	155
Mulline Surprise lease	155
Mulwarrie	108, 114
Murchison Goldfield	98, 99
Mystery lease	136, 138, 139, 144, 152, 153, 155
 New Find lease	155
Newportite	64
New Westward Ho lease	35
Nicolay, Rev. C. G.	80
Nil Desperandum lease	155
North-East Coolgardie Goldfield	100, 101
Nullagine Series	83
 Off Chance lease	142, 148-150, 157
<i>Olanellus Forresti</i>	84, 85
Ora Banda	108
<i>Ostrea</i>	89
Ottrelite	64-69, 71-73, 77, 78
Our Luck lease	155
Ovens lease	36, 39
Overlander lease	155
 <i>Pachypora</i>	86
Paddington	108
Palaeozoic Rocks	79
Peach Tree lease	158
Peak Hill Goldfield	98
<i>Pecten</i>	89
<i>Perisphinctes Championensis</i>	87
Permo-Carboniferous Rocks	86
<i>Peronella</i>	88
Perseverance lease	155
<i>Phillipsastraea</i>	86

INDEX—continued.

	Page
Phillips River Copper Field.. .. .	103
Phyllite	64
Physiography	80-82
<i>Pila</i>	8
Pilbara Goldfield	94-97, 104
Pirate lease	155
<i>Planter</i>	9
<i>Pollicipes</i>	88
<i>Polyzoa</i>	86, 89
Poona	55
Porcupine Group	46
Porcupine lease	48
Porphyries	20
Pre-Cambrian Rocks	79, 82, 93
Pride of the Hills lease	155
Prodigal lease	155
<i>Productus</i>	86
<i>Do. Abichi</i>	87
<i>Do. opunta</i>	87
<i>Do. subquadratus</i>	87
<i>Do. tennistriatus</i>	87
<i>Do. tumidus</i>	87
<i>Do. undatus</i>	87
<i>Proetus</i>	86
<i>Pulvinulina</i>	9
Puzzle lease	157
Queen Mary lease	155
Queen of the Earth lease	23, 26, 36, 37, 41, 43
Recovered Rights lease	155
Redleap Extended Explorers, Ltd.	157
Redleap lease (see Cardinal lease).	
Refuse lease	155
Reggie lease	155
Reprieve lease	150, 155
Revenue lease	157
<i>Rhizoma</i>	9
<i>Rhynchonella</i>	86
Riverina	108, 116
Riverina G.M. Co., N.L.	158
Riverina lease	141, 150, 151, 158
Riverina Main Reef lease	155
Riverina No. 1 North lease	155
Riverina North Extended lease	155
Riverina North lease	155
Riverina Perseverance lease	155
Riverina South lease	141, 150, 151, 158
Riverina Star lease	155
Rose and Shamrock lease	155
Salmite	64-66, 78
<i>Salterella Hardmani</i>	84, 85
Scheelite	55
Schnider lease	156
Shamrock lease	150, 157
Shamrock North lease	157
Silurian Rocks	85

INDEX—continued.

	Page
Sismondine	64-66, 78
Six-Mile	107
Sommer, Dr. F. von	80
Speakman's Well	114
Spin of the Coin lease	132
<i>Spirifera</i>	86
<i>Do. Hardmani</i>	87
<i>Do. Marcoui</i>	87
<i>Do. lata</i>	86
Split Rocks Belt	168, 109
Standard lease	156
Stirling Range Series	85
Struverite	64
Superficial Deposits	145
Syenite	18
 Tasmanian lease	 155
Tertiary Rocks	80, 89
Three Gins' lease	155
Thunderbolt lease	152
Tin Dog lease	38
Tin Fields	104
Trio lease	157
<i>Truncat lina</i>	9
Try Again lease	155
Tungsten	55
<i>Turitella</i>	89
 Ularring	 108
Ularring Rocks	116, 132
 <i>Valentina</i>	 9
Venasquite	64-66
Vera lease	156
<i>Vertebraria</i>	9
Vettersburg	107, 108, 110
Victoria Extended lease	156
Victoria lease	147, 150, 156
Victorian lease	156
Victoria South lease	156
Victory lease	156
Viola lease	23, 25-27, 32, 33, 39-41
 Wangine Soak	 119-121
Wangine-Ularring Belt	108, 111
Waratah lease	156
Warriedar lease	48
Waverley	108, 111, 121
West Melba lease	19, 23, 34, 35
West Pilbara Goldfield	97, 102
Westward Ho lease	36, 39
Wolfram	55
Woodward, H. P.	80
 Yale Lock lease	 157
Yalgoo Goldfield	98, 99
Yampi Sound	64
Yankee Doodle lease	156

INDEX—*continued*.

	Page
Yerilla	13
Yerilla King lease	19, 23 32, 39-41, 43
Yerilla King Southern Extension (<i>see</i> Viola).	
Yilgarn Goldfield	98-100
Young Australian East lease	156
Young Australian lease	150, 156, 158
Young Australian North lease	156
Young Boulder lease	156

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1915.

WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 65.

THE
REPUTED PETROLIFEROUS AREA
OF THE
WARREN RIVER DISTRICT
(SOUTH-WEST DIVISION),

BY

H. P. WOODWARD,

ASSISTANT GOVERNMENT GEOLOGIST.

WITH

A CONTRIBUTION ON ASPHALTUM FROM THE
SOUTHERN COAST OF AUSTRALIA,

BY

E. S. SIMPSON, B.E., B.Sc., F.C.S.,

AND

A PETROLOGICAL CONTRIBUTION

BY

R. A. FARQUHARSON, M.A. (OXON.), M.Sc., F.G.S.

*Issued under the Authority of the Hon. P. Collier, M.L.A.,
Minister for Mines.*



PERTH:

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PREFATORY NOTE.

—o—

ATTENTION having been once more directed to the Warren River Valley, which rose into prominence during the disastrous oil boom of the years 1902-04, it was decided that a re-inspection of the district should be made and the evidence such afforded re-investigated.

Field work was commenced in the district by Mr. Woodward early in February, 1914, and continued until about the end of the following month.

The area examined amounts to about 1,000 square miles, and the results published on two sheets on the scale of four miles per inch. The country under investigation falls within sheets 1 and 7 of the 300-chain series of maps issued by the Department of Lands and Surveys.

Owing to the configuration of the country, very few natural sections are visible, though such boring as has been carried out has resulted in a little additional information as to the underground geology. These conditions prevailing, Mr. Woodward's investigations had, perforce, to be chiefly directed to the collection and sifting of such published and other information as had accumulated since the district was first visited and reported on by myself in 1902.

The report, which makes up this Bulletin, contains practically no new geological facts, and merely bears out, while emphasizing the conclusions set out in the official telegram from myself to the Minister for Mines, dated the 18th of March, 1902:—

“Have examined the reputed petroliferous district of the Warren and the Donnelly, and from all the evidence available, I regret to report that the hope that the neighbourhood will rise to any importance as an oil-bearing district cannot reasonably be entertained.”

A handwritten signature in dark ink, reading "A. G. Mackenzie". The signature is written in a cursive, flowing style with a long, sweeping underline.

GOVERNMENT GEOLOGIST.

Geological Survey Office,

Perth, 1st March, 1915.

TABLE OF CONTENTS.

Prefatory Note	Page 3
I.—Introduction	7
II.—Government Regulations controlling the Prospecting for Oil in this State	8
III.—History of Prospecting Operations for Petroleum in the Warren River District	8
IV.—Previous Literature	9
V.—Physiographical Geology	17
VI.—Grounds upon which the occurrence of Petroleum in the Area under review was based	20
i.—The presence of Bitumen or Asphaltum on the beach ..	21
ii.—Oil-like scum on the Sea and upon certain inland waters ..	24
iii.—So-called Bitumen Clay and Rock from the bed of the Warren River	26
iv.—Coal Deposits at Fly Brook	27
v.—Reports upon the Petroliferous character of the District	28
vi.—Evidence afforded by the bores	33
VII.—Conclusions	37
Appendix I.—Asphaltum from the Southern Coast of Australia ..	40
Appendix II.—Petrological descriptions of some rocks from the Warren River District	49
Index	53

LIST OF MAPS.

- Frontispiece:—Map showing the S.W. Division of Western Australia
and Area described.
- Geological Sketch Map of the extreme South-Western portion of
Western Australia. (2 sheets.)

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA.

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The Reputed Petroliferous Area of the Warren River, South-West Division.

I.—INTRODUCTION.

Owing to the great and ever-increasing importance which attaches to deposits of mineral oil, the Federal authorities in 1913 requested the Government of this State to supply them with the fullest particulars regarding any existing deposits of petroleum, and also with any reports upon those areas which gave promise of containing it.

Later on in the same year (1913) the Hon. the Prime Minister informed the Hon. the Premier of this State that his Government had secured the services of Dr. Arthur Wade, who had specialised in oil geology, to report upon the Petroliferous deposits of New Guinea, and should the State Government desire to secure his services at the expiration of his engagement with the Commonwealth, arrangements could possibly be made to do so.

With the object of determining what action should be taken, the Hon. the Premier instructed this Department to furnish him with reports upon all the known and possible oil areas of this State. Since, however, no exhaustive examination had, up to that time, been made of the reputed Warren-Blackwood petroliferous area, the writer received instructions, in the early portion of this year (1914) to undertake this piece of work.

The area under review covers, approximately, 1,000 square miles; it extends along the south coast from Black Head to Flinders Bay and northward to the Blackwood River, eastward to the Darling Range, and westward to the Leeuwin-Naturaliste Range, or between 34deg. 5min. and 34deg. 45min. S. Lat. and 115deg. 10min. and 116deg. E. Long.

Of this area only about 680 square miles was found to be free from granite outcrops, therefore, for the purpose in hand, attention will be entirely confined to this portion. That this basin extends northward of the Blackwood River to Geographe Bay, being bounded upon the east by the Darling Range scarp fault, and on the west by the Capes Naturaliste-Leeuwin granitic outcrop, is conclusively proved by the evidence afforded by the numerous bores put down in the northern section of this area; but since this portion

of the basin was examined and reported on by Mr. E. C. Saint-Smith, Field Geologist, in the year 1912* a further inspection was deemed unnecessary.

All the work of a chemical nature in connection with this report has been executed by Mr. E. S. Simpson, B.E., B.Sc., Chemist to this Department, who is also responsible for Appendix I., entitled "Asphaltum from the Southern Coast of Australia," while Appendix II., entitled "Petrological Description of some Rocks from the Warren River District," is contributed by Mr. R. A. Farquharson, M.A., M.Sc., Departmental Petrologist.

II.—GOVERNMENT REGULATIONS CONTROLLING THE PROSPECTING FOR OIL IN THIS STATE.

Oil is defined in the Mining Act as mineral oil, shale, bitumen, or any carbonaceous mineral fuel, except coal.

A prospecting area may be marked off not exceeding 3,000 acres in extent.

Such area shall be continuously worked after the expiration of thirty clear days from the date of registration by not less than three men for every one thousand acres or fraction thereof.

III.—HISTORY OF PROSPECTING OPERATIONS FOR PETROLEUM IN THE WARREN RIVER DISTRICT.

Although the presence of Asphaltum upon the southern coast of this State has been known for a considerable number of years, it does not seem to have been connected with the possible presence of Petroleum springs until the year 1901, its origin being assumed as sea-borne, probably from some distant source. This conclusion was arrived at owing to its occurrence only upon the coast above high water mark, where it was associated with a heterogeneous assortment of material which has been thrown up in stormy weather.

In the year 1901, however, a considerable amount of excitement was caused by the reported discovery of petroleum in this district by Messrs. Sinclair and Boyd, financed by a few Perth people who designated themselves "The Western Australian Mining Syndicate." This syndicate secured several Prospecting Areas, and floated a company styled "The Westralian Mining and Oil Corporation, Ltd.," by whom Mr. E. J. Nankivell was appointed manager.

The reported discovery of petroleum caused many "bush-folk" of the district to suddenly come to the conclusion that they had seen indications of oil at different places, and frequently that they had noticed that their tea had a strong and disagreeable flavour of kerosene when made from water obtained in certain localities. Such was the excitement that promoters had little difficulty in float-

* A Geological Reconnaissance of a portion of the South-West Division of Western Australia, W.A.G.S. Bulletin No. 44.

ing syndicates upon the strength of such statements, the result being that the district was over-run with "oil experts" and prospectors, who pegged out huge tracts of country, 30,000 acres of which were eventually applied for as mining tenements and granted.

IV.—PREVIOUS LITERATURE.

The first official report relating to this area is entitled "The Reputed Petroliferous Deposits of the Warren and the Donnelly Rivers," by A. Gibb Maitland, Government Geologist, published in the Annual Report of the Geological Survey for the year 1902, p. 13, *et seq*, in which he says:—

The formations exposed consist of:—

- (a.) Superficial deposits comprising sand dunes, alluvial deposits, etc.
- (b.) Basaltic lavas.
- (c.) A series of sandstones, grits, clays, shales, and coal seams.
- (d.) Crystalline rocks which form the floor upon which the other formations were laid down.

He remarks that no sections are exposed in the Warren River, with the exception of outcrops at one or two points of cement, discoloured with vegetable matter—in reality a carbonaceous sandstone resting upon a peaty clay floor of no great thickness. Samples from each of which proved, upon examination in the Department Laboratory, not to contain any trace of oxidised petroleum residues.

The valley of the Donnelly he describes as being similar to that of the Warren, with the exception that basaltic lavas rise at one or two points above the surface, and that in the bed of one of its tributaries a series of sandstones, grits, and clay shales, together with one or two coal seams, are exposed.

In conclusion he says:—

In the light of our knowledge of the geological structure of the valleys of the Warren and Donnelly, it may be reasonably doubted whether the district can in any sense be regarded as being petroleum-bearing. No petroleum has been discovered in the district, nor does its geological structure seem to conform to that which regulates the occurrence of oil elsewhere.

The next report, other than those published in the newspapers, was by Mr. S. Göczel and was issued in pamphlet form by the Westralian Mining and Oil Corporation, Ltd.,* for whom it was written. He states that this basin occupies the site of a one-time ingression into the present South-Western portion of the State. The coastal hills consist of coral limestone and coral sand resting on stratified fossiliferous sandstone which is occasionally overlaid by basaltic flows. A good section of this is exposed about three-quarters of a mile west of Black Point where the basaltic columns attain a height of from 25 to 30 feet above sea level. The sandstone at the contact is altered for a lateral distance of several hundred

* A copy of this Report may be seen at the Geological Survey Office.

feet, it having become highly ferruginous, while the dynamic effects of the flow on the underlying sandstones are also visible. He further says that owing to this contact alteration of the sandstone, casts of the fossils have been preserved. These consist largely of brachiopods, but he also noticed impressions of encrinites in sandstone, the specimens of which resembled recent genera. A slab of rock containing a small saurian a few inches in length was observed, head, vertebræ, with ribs, a comparatively long tail, and the hind leg, with bird-like toes, also were imprinted. Petrified vertebral bones from small saurians occur also on the contact planes between the sandstones and the coral-rock.

Basaltic scoria, conglomerates and tufas, with occasional outcrops of zeolitic basalt from the north-eastern fringe of the Warren Blackwood basin in the form of ridges, conical hills and banks lean northwards against the Archæan crystalline rocks. This rock is well exposed in Barlee Brook, near Mr. Dickson's.*

Selected specimens will show the gradual progress of alteration from zeolitic basalt to the conglomerates and gravel bank, which, in consequence of their ferruginous character, are popularly known as ironstone conglomerates and ironstone gravels.†

These conglomerates and gravels are the one-time scoria, lapilli and ashes of the basaltic eruptions, and cover for miles the surroundings of the old volcanic centres.

The lime was leached from this rock and carried to the sea, thus causing great activity amongst the coral polypi. He considers that the Darling Range was much higher and that deep water then covered this basin, which was gradually built up by the wash-off from the land. Then numerous volcanoes burst up from the shallow sea, which supplied lime to the coral building polyps which built up a barrier reef along the present coast-line, enclosing a sheet of shallow water between these and the range. This area then gradually rose until the water was drained off, with the exception of the existing swamps. The coastal sandstone in connection with the basaltic volcanic feature claims the principal attention, while the organic matter was supplied by marine life on one side of the basin and vegetable matter from the hill on the other.

These coastal sandstones, he says, appear almost flat in the western, gently undulating in the middle, and moderately corrugated in the eastern portion of the basin. From the mouth of the Donnelly River to Black Head anticlinal features of the coastal sandstones rise gradually higher and higher above the sea level and form the sand-dune covered coastal hill range through which the Warren River and Meerup Brook have cut.

Mr. Göczel considers that the oily scum upon the sea is bitumen in a finely divided state which gradually consolidates near the

* Donnelly River, near Scott's, [13714], p. 51, H.P.W.

† Laterites, H.P.W.

outer breaker line forming an ice-like sheet, the edges of which are broken up in stormy weather when some of the detached portions are thrown up upon the beach.

The finding of this bitumen upon the coast he considers a sign of the bituminous character of some near fossiliferous rock feature but not necessarily an indication of petroleum. In conclusion, Mr. Göczel states that he believes that the lower horizons of the coastal sedimentary strata will prove to be petroleum-bearing.

The next report published is an official one by Mr. A. Montgomery, M.A., State Mining Engineer, which appeared in the Annual Report of the Mines Department for the year 1903, p. 95 *et seq.* This was written after an examination of the whole supposed petroliferous area, conducted under the guidance of Mr. W. L. Brockman, an old resident of the Warren District, and Mr. E. J. Nankivell, the local representative of the Westralian Mining and Oil Corporation, Limited, which latter was making application to the Government for financial assistance.

In this report he states that along the beach between Black Head and Augusta there is a belt of hilly country which varies from two to three miles in width, some of the highest points of which attain an elevation of 800 feet. These, he says, are very like sand-hills and are often covered by recent sand-dunes. They are composed of sandstones and limestones which usually show in section distinct stratification with a general easterly dip of 20 or 30 degrees. This varies considerably in a short distance but is much too regular, in his opinion, to be the result of wind formation. The limestones, he states, are composed largely of comminuted shell fragments, forming a shell sand, which when cemented together forms a hard rock, the laminations in which are similar to the sandstones. He does not agree with Mr. Göczel in his theory of an anticlinal fold, said to be visible in the large sections in the Meerup Brook, Warren and Donnelly Rivers, since the main beds of the strata are lying approximately horizontally, while the individual beds often present splendid examples of "false or current" bedding, probably due to their deposition in shallow water.

Mr. Montgomery considers that they were laid down in a large lagoon, which was cut off from the sea by an intervening range of sand-hills. He lays considerable emphasis upon the distinction that the sandstone and limestone hills were not old sand-hills hardened into rock, but sediments laid down in the lagoon and on the ocean beach, which have hardened into stone and have since been raised and carved into their present shapes by erosion.

This theory, he considers, is supported by the occurrence of fairly heavy shells enclosed in places in the sandstone and a coarse bed of conglomerate containing fairly large pebbles of an older crystalline limestone far too heavy to have been moved by the wind. This latter rested directly upon the Archean rocks which outcrop at

Malamup. The basalt, he considers, was deposited as sheet flows after the deposition of the sandstones and limestones and is of considerable importance in consideration of the possibilities of finding oil. He does not consider that the bitumen on the coast, nor any of the so-called exudations of oil are of any material value, since the former is probably a foreign substance, while the latter did not prove to be petroliferous.

Mr. Montgomery does not consider that the geological structure of the district is either particularly favourable for the occurrence of oil or discouraging, since it has been discovered in strata of similar age elsewhere, while in other localities similar rocks have been penetrated over and over again without a trace of oil being obtained, and also many of the bores already put down in this State have passed through strata of quite as promising a character without encountering traces of petroleum.

The Warren oil bore does not pass through an impervious shaly stratum above the sand-beds which are considered favourable for the retention of oil in underground reservoirs, and he does not consider that there is any anticlinal folding, the presence of which is a condition favourable to the collection of oil underground; all the evidence he obtained seems to indicate a fairly horizontally bedded strata.

The State Mining Engineer concludes his report as follows:—

The chances appear to me, therefore, to be greatly against success being likely, and I am not able to certify under Part V. of the Mines Development Act that there is a reasonable prospect of success.

Nevertheless he considers the question of such importance that he recommends the Government, in order to settle it once and for all to subsidise the Company at the rate of £1 for £1 upon money expended by them upon deeper boring.

In his monograph entitled “Kerosene Shale Deposits of New South Wales,” Mr. J. E. Carne, F.G.S., Assistant Government Geologist, N.S.W., says:—

Asphaltum is usually found to be the result of atmospheric action upon petroleum when the latter rises to the surface of the ground, and therefore when found *in situ* is to be looked upon as a valuable indication of the presence of underground stores of petroleum.*

In reviewing other reputed petroliferous deposits under the heading of “Western Australia,” Mr. Carne says:—

In 1871 the Rev. W. B. Clarke, writing of petroleum springs in Australia, among other localities mentioned, stated “In New South Wales there are two localities known to me for many years, in which petroleum exudes; and there are two or three in Western Australia the products of which I have examined. Nothing of value has yet been found.”†

The first definite indications of petroliferous deposits in this State are recorded in the Catalogue of the International Exhibition

* Memoirs of the Geol. Survey of N.S.W., Geology, No. 3, 1903.

† Industrial Progress, New South Wales, 1871, p. 519.

of 1866-7.* In the Western Australian section, P. Walcott exhibited—

A most interesting series of bitumens, resins, inflammable amber-like minerals, peat, and chalk. The inflammable substance is of a dark brown colour, resinous fracture, and soluble in alcohol. The bitumen or asphaltum is free from sulphur compounds, and is, therefore, of value if occurring in quantity. One of the resins closely resembled copaline. On distillation it yielded an oil like oil of amber; this specimen was marked amber. A second, also marked amber, seems to represent a transitional change from the former, which again seems connected with specimens marked "peat," which consists of sand grains coated and cemented by a peaty substance soluble in potash. All these were found in beds near the coast.

During the present year (1903) reports of the existence of oil springs in Western Australia have been revived, the localities being the Warren and Donnelly Rivers, between Cape Leeuwin and Point D'Entrecasteaux on the coast. Mr. A. Gibb Maitland, Government Geologist, who recently examined the sites indicated, was unfavourably impressed with the indications, which did not, in his opinion, warrant the reports circulated as to the prospects of successful developments.

As the reports, however, are so circumstantial, and supported to some extent by the undoubted occurrence of asphaltum and backed by the investment of capital, it has been deemed wise to insert some of the most substantial, with the authorities for them.

In the "Sydney Morning Herald" of the 5th February, 1902, the following paragraph appeared under the heading of "Mineral Oil in Western Australia":—

It is reported that there have been important developments recently in connection with the petroleum and asphalt discoveries in the vicinity of Warren River, and that arrangements have been made to test the country, a contract having been entered into between the Westralian Mining and Oil Corporation (Limited) and the Diamond Drilling Company of Kalgoorlie to sink a trial bore to a depth of one thousand and five hundred feet. For many years past, it is stated, settlers in the vicinity of the Warren River, which is on the southern coast of Western Australia, have known that bituminous deposits were to be found along the coast between Capes D'Entrecasteaux and the Leeuwin; but until quite recently the matter was regarded as one of scientific interest only. Recent, developments, however, in connection with the use of "liquid fuel" led a few months ago to the despatch of two prospectors, Messrs. Boyd and Sinclair, to examine the country. At one point indicated by residents oil could be seen floating on the sea a few hundred yards from the shore. Samples of the sea-water were obtained by the prospectors and subsequent analysis showed that the oil was of mineral and not vegetable origin as had at first been feared. Along the shore masses of asphaltum were found, apparently cast up by the waves. The analyst, Mr. S. S. Dougall, F.I.C., reports that this is a singularly rich asphaltum, being for all practical purposes pure, only a minute proportion of foreign mineral matter (dry sea-sand) being present.

A little further inland traces of mineral oil were found in the sand-dunes, and at a distance of about three miles from the shore sandstone saturated with petroleum oil was found in the watercourse of the Warren

* Official Record, Melbourne, p. 169.

River. A curious feature in connection with the matter, it is reported, is that the geological conditions appear to be identical with those of the oil regions of the Californian coast where the same phenomena of oil on the sea near the shore and the presence of bituminous asphalt thrown up by the tide are observed.*

The "Australian Mining Standard," 20th March, 1902, reported that—

Mr. Simpson, Mineralogist and Assayer to the Geological Branch of the Westralian Mines Department, has furnished the Under Secretary for Mines with an exhaustive analysis report on the samples of bitumen found near the Warren River, on the South coast. One of the samples yielded 49.47 per cent. of petroleum and 49.37 per cent. of asphaltine. Mr. Simpson remarks that this material must be regarded as extremely pure, and only comparable to the best Syrian and Bermuda asphalt. He adds that, where found in samples of this character, it is regarded as a valuable indication of the presence of underground stores of oil. A boring plant has been sent to the locality to prospect for the supposed oil.†

E. J. Nankivell, on the 29th May, 1902, in the same journal, writes:—

On the south-west coast of Australia there is a large tract of heavily timbered karri and jarrah country. It is practically unpopulated. Roads lead from Bridgetown and Busselton to portions of the coast. For many years it has been noticed that after a heavy north-west storm large quantities of bitumen in pieces upwards of 400 lbs. in weight, still viscid and ragged as if recently torn from the fissures from which it exuded, have been cast up on the beach some forty chains west from the mouth of the Warren River. On the sea at this place there is a thick seum of reddish-brown hue, which, as the sun shines on it, gives forth a most beautiful array of prismatic colours. Analysis proves this to be petroleum. The bitumen is of high specific gravity and exceptionally pure. It contains 95.2 per cent. of bitumen matter. A similar seum occurs for many miles along the beach, but in no place is it so thick and luminous as at the spot mentioned. Elsewhere bitumen is also found cast up, but in pieces not larger than one's two hands. Shales taken from the Warren River, five miles inland, contain 7.2 gallons per ton, and sand rocks all have a trace of petroleum. The surface of the river is coated with a film of light oil. Where the water is impeded it collects readily in company with vegetable matter. It can be captured in sufficient quantity to prove that also it contains an appreciable quantity of the heavier form of oils. From the bed of Warren River and bore hole gas is constantly ejected.‡

Mr. Carne more recently, whilst giving evidence before the Interstate Commission on the Shale Oil Industry, in reply to the question "Are there any possibilities of oil wells in Australia"? said:—

As far as I know there is no indication of oil wells of any value. There has been some encouragement in South Australia and in parts of Western Australia near the Australian Bight, but so far results

* For many years prior to the oil strike at Beaumont, Texas, it was rumoured that oil floated on the sea just west of Port Sabine, about 24 miles distant (*vide* R. T. Hill, Journ. Franklin Inst., 1902, CLIV. (3), p. 320).

Off the coast of Trinidad liquid bitumen floats on the water. Asphaltum glanee is also found on the beach at Guapo and Guayquayare, especially after stormy weather. (G. P. Wall and J. G. Sawkins, Rept. Geol. Trinidad, 1860, p. 139.)

† Vol. XXI., No. 697, p. 380.

‡ Austr. Mining Standard, 29th May, 1902, XXI., No. 707, p. 728. S. Göczel has also more recently reported on the Warren-Blackwood Basin. (Perth, W. Aust., Oct. 16th, 1902, pp. 1-8.)

have not been great. Still, I don't consider that the possibilities have been exhausted. One bore in Western Australia passed through a three inch seam of bitumen.

Besides the reports before referred to, a vast quantity of matter appeared in the local press, most of which was from the pens of directly interested persons; they consisted largely either of distortion of fact or abuse of Government officials and other independent Mining Engineers (including the writer, who at the time was in private practice) who reported adversely; consequently no reference is made to these here.

In the Annual Report of the Geological Survey for the year 1913, Mr. A. Gibb Maitland, the Government Geologist, dealt with the reputed occurrence of oil in Western Australia in the following terms:—

In October a memorandum on the reputed occurrence of oil in Western Australia was prepared and submitted to the Government. This memorandum dealt solely with the facts as ascertained by personal investigation and boring in the State, and did not in any way touch upon the fascinating and much debated scientific question as to the origin of petroleum and cognate points. The memorandum, which was printed *in extenso* in the Western Australian press for public information, and became the subject of questions in Parliament, reads as follows:—

In a pamphlet by Mr. Geo. D. Mendell, in September, 1913, entitled "Petroleum Exists in Australia," and issued by the Artesian Oil Wells Company, there appear statements regarding oil in Western Australia about which it is desirable that the investing section of the public should receive timely warning:—

I.

On page 4 of the pamphlet it is set out:—

"The floor of Albany Harbour, West Australia, is of bituminous formation, and to the south is covered by impervious strata of limestone. Where the limestone capping was broken when dredging the harbour, traces of oil were discovered and in several instances the flow of oil lasted several days. Six bores were put down in the harbour, the deepest being only 105 feet, but oil was found in two of the bores. To the west of the harbour are large beds of limestone and sandstone, and oil and bitumen have been frequently found for many years past. Petroleum will most assuredly be found by boring to a depth of, say, 2,000 feet."

The belief in the occurrence of oil bearing rocks at Albany led, in 1906, to the formation of the Princess Royal Harbour Mineral and Oil Company, and to an application to the Government for State aid in the prosecution of boring operations "*to ascertain the strata, to locate the anticlinal axis.*"

A personal inspection of the harbour and its surroundings was made by myself and a report, accompanied by a geological map, prepared and submitted to the Government; this document and map were published early in 1907 in Geological Survey Bulletin No. 26, under the title of "The Geology of Princess Royal Harbour with reference to the occurrence of Oil."

This report showed the harbour to be very shallow and to be everywhere underlain by granite and allied rocks, which were met with in two of the bores put down by the Mineral and Oil Company at 46 and 48 feet respectively. The low ground round the harbour had also been pierced by bore holes and in every case was the floor of crystalline rocks met with, the greatest depth being 234 feet. After dealing exhaustively

with the geology of the harbour the report further set out that there is nothing in the geological constitution and structure to in any way indicate that the occurrence of mineral oil is probable, whilst the wrong hypothesis as to the source of the bitumen dredged up, and the oil floating about on the surface of the water, appears to have led to money being needlessly spent in boring, etc.

In November, 1912, Mr. Geo. D. Meudell, the author of the pamphlet, wrote asking to be supplied with any reports, plans, etc., bearing on the subject of petroleum in Western Australia, and a copy of the Bulletin containing the official report and map on the Geology of Princess Royal Harbour, was duly supplied to him.

II.

On page 5 of Mr. Meudell's pamphlet it is stated:—

“The Warren-Blackwood oilfield, east of Cape Leeuwin, has been favourably reported on by Mr. S. Göczel, a famous Hungarian geologist, who claims that oil will be struck by boring to a sufficient depth.”

In 1901 application was made by the Westralian Mining and Oil Corporation for State aid to bore for oil in the Warren and Donnelly Rivers, and after a personal inspection of the district in question by myself, a report, “The Reputed Petroliferous Deposits of the Warren and the Donnelly Rivers,” was prepared and submitted to the Government.

In this report it is set out that:—

“In the light of our knowledge of the geological structure of the valleys of the Warren and the Donnelly it may be reasonably doubted whether the district can in any sense be regarded as petroliferous.”

No petroleum has been discovered in the district, nor does its geological structure appear to conform to that which regulates the occurrence of oil elsewhere. In consequence the application for State aid was refused.

At a later date the Oil Company again approached the Government for assistance to continue the boring operations which had been started. The State Mining Engineer, after visiting the district, reported to the Government:—

“On the prospects of discovering petroleum by boring in the Warren River district, in which it was set out that the formation was not unfavourable for oil, though not specially promising either, and that there is the positive fact that bitumen, a product of oil, has been repeatedly and continually found in the district for many years past.”

Boring was carried down to a depth of 1,719 feet. No oil was found and the last 1,000 feet penetrated angular sand, of quartz felspar and pale garnets, such as owes its origin to the disintegration of the crystalline rocks upon which the strata of the Warren and the Donnelly Rivers rest, and which outcrop to the north.

The various reports were published in the Annual Reports of the Mines Department for the years 1902, 1903, and 1904.

III.

Mr. Meudell's pamphlet, part 5, states:—

“The geological map of West Australia shows the correct oil bearing tertiary rocks fringe the coast from Cape Leeuwin to Derby on King's Sound.”

Over 110 bores have been put down in the sedimentary rocks (Tertiary or Devonian) which form a relatively narrow fringe in the maritime districts from Eucla to Wyndham.

In the Kimberley Division there are 9 bores, in the North-West 24, in the South-West 67, and in the Eucla Division 9, without any trace whatever of oil being found.

These are the only districts of the State in which petroleum can occur, if such exists, of which at the present time there is no evidence.

V.—PHYSIOGRAPHICAL GEOLOGY.

The area under review is situated near the extreme south-western corner of the State, being bounded on the north by the Blackwood River, on the south by the Southern Ocean, on the east by the Darling Range fault line, on the west by the Naturaliste-Leeuwin granite belt, or between 115deg. 10min. and 116deg. E. Long. and 34deg. 5min. and 34deg. 45min. S. Lat., covering an area of about 1,200 square miles.

SURFACE CONFIGURATION.—For general purposes the surface of this area may be described as an inclined plain, the general fall of which is in a south-westerly direction, or from the Darling Range towards Cape Leeuwin. This area will be described under three heads, the first of which embraces what may be called the foot-hills, the second the coastal plains, and the third the ancient and modern sand-hills.

The Foot-hills.—Under this heading a tract of country may be described that lies between the Darling Range and the coastal plain. It consists of a broken hilly area the numerous ridges being gravel capped* and thickly timbered; these rise to an elevation of from 50 to 150 feet above the intervening sandy scrub-covered flats which have a mean elevation of 200 feet above sea level.

The Coastal Plains which form the next belt are apparently nearly dead level and of little elevation above the sea. They are sandy, swampy, and in part covered by a low dense scrub.

The Ancient and Modern Sand-dunes form an elevated belt along the coast, attaining an elevation of from 200 to 750 feet in places; they are often thickly covered by vegetation which is quite impenetrable on horse-back. The flats between these hills are sometimes swampy, but the more elevated valleys are usually well grassed.

The coast of this section runs in a north-westerly direction and consists for the most part of a wide sandy beach at the base of the sandstone cliffs or dunes.

GEOLOGY.—As already mentioned, this area is bounded upon the eastern side by the Darling Range which is in this locality composed of crystalline schists. This formation terminates so suddenly along a practically north and south line as to indicate the presence of a fault, the down throw being presumably upon the western side. This was proved to be the case by a bore put down on the western side of the Warren River, not far from the escarpment, which penetrated reconstructed strata to a depth of 1,700 feet without encountering the crystalline rocks.

The Foot Hills.—The rocks which lie upon the western side of this fault scarp have been proved by a number of bores put down some years ago upon the Fly Brook to consist of a series of mica-

* Nodular laterite.

ceous shales (sometimes carbonaceous), sandstones, grits and shingle beds with seams of brilliant black lignite.

The hills in this area, as before stated, are thickly timbered and covered with lateritic gravel, while the flats are usually sandy with here and there patches of deep red loam in the vicinity of the basaltic outcrops, which rocks are the only ones exposed at the surface.

One of these outcrops is mentioned by Mr. A. Gibb Maitland, the Government Geologist, in 1902* situated on Loc. 66/330, a little north of Mt. Silver, near the mouth of the Donnelly River, which consisted of a vesicular basalt [3452] whilst beds of similar rock outcrop at Black Point, the mouth of the Donnelly River, Darradup, on the Blackwood River,† and are also stated to have been passed through in the Warren River bores (this latter, however, lacking in official confirmation). There is little doubt in the writer's mind but that the Fly Brook beds are the southern extension of the Donnybrook series, which are well developed along this same belt of country northward of the Blackwood River. The deep bore on the Warren River passed through this formation for about 500 feet, beneath which only granitic sand was encountered. As there is little doubt but that these rocks form a portion of the Donnybrook series, and since this latter is possibly of the same geological age as the Collie beds, they may be provisionally classed as Permo-Carboniferous.‡

Coastal Plains.—In this section no rock outcrops occur, the whole area being covered by sandy flats or swamps. This area has evidently at no very remote period been covered by a large but shallow sheet of water caused by the damming back of the rivers by the coastal sand-dunes. A similar phenomenon is observable all along the coast between Cape Leeuwin and Albany. In the area under review this coastal barrier has now been cut through at three points, the first being on the western edge of the basin near Augusta where the granite rocks outcrop, and it is here that the Blackwood and Scott Rivers discharge themselves into the sea at Flinders Bay, while the Donnelly and Warren Rivers have broken through the barrier further to the eastward.

The Blackwood, Donnelly, and Warren Rivers take their rise on the Darling Peneplain and are amongst the few perpetually flowing streams of the State, while the Scott River, which flows in a north-westerly direction, is merely the remains of the old drainage channel situated at the back of the dunes which carried the waters of the Warren and Donnelly Rivers to Flinders Bay prior to the cutting of the sand-hills further eastward.

At the present time this river is more correctly described as a series of swamps into which the coastal plain lying to the westward of the Donnelly and south of the Blackwood drain, the direction of

* Annual Report of the Geological Survey for 1902, p. 14.

† See Appendix II., [3452] and [12715-6-7].

‡ See G.S.W.A. Bulletin, No. 44, p. 23.

this drainage being deflected to the north-westward by the Coastal Hills. Over this area beds of peaty brown coal are of fairly common occurrence, but these are of much more recent date than the Fly Brook Series and were evidently formed while this area was still a fresh water lagoon.

Ancient and Modern Dunes.—The rocks of this area are of two distinct ages; the modern, which consist entirely of sand-drifts, often attain considerable magnitude; they are piled up by the wind over the older series represented by calcareous sandstone and limestone, which in all sections exposed exhibit such well-marked drift bedding as to make their aeolian origin quite apparent.

The origin of the calcareous matter is evidently due to the fact that the wind piled up considerable quantities of shelly and coralline fragments with the sand, which was subsequently converted into calcareous sandstone by the action of the permeating meteoric waters charged with carbonic acid.

Owing to the very pronounced regularity of the bedding it often presents a striking resemblance to stratification. This uniformity is, however, clearly due to the fact that the prevailing winds blow from the south-west, while a careful examination reveals the fact that the bedding is often cut by floors formed by the removal of portions of the deposited sand by gales blowing from another direction, while the original dip of the bedding is found to continue above this break after a further deposit of sand was piled up by the wind on its return to its normal quarter. This stratification is much too regular to represent current bedding.

The No. 3 bore put down on the Warren River at about one mile from the coast in the midst of a modern sand-drift passed through 80 feet of incoherent sand and then entered the Fly Brook Series without encountering the calcareous sandstone beds, thus clearly supporting the dune theory.

The geological age of these rocks is as yet undetermined, but that they are of comparatively modern origin there can be little doubt, since they are only met with immediately along the present coast line. Had they belonged to a more remote geological period some departure from this rule would be expected (as is the case in the Bight where the rocks belong to the Eocene Period) since it is scarcely probable that the outline of the coast would have remained unchanged over so considerable a geological epoch.

It is highly probable that a considerable amount of subsidence continued to take place along the Darling Range fault subsequent to the formation of the ancient sand-dunes, since the coastal hills in the area between the Warren and the Donnelly Rivers consist almost exclusively of recent sand-dunes. This would also account for the fact that the rivers have breached these hills at this point.

With the exception of two points, viz., Black Point and the mouth of the Donnelly River, where basalt outcrops, the rock upon

which these ancient dunes rest is not exposed, while after a careful examination of these points it becomes quite clear that the basalts are of a greater antiquity and existed in the form of reefs prior to the piling up of the sand-dunes. This is demonstrated by the fact that pebbles and boulders of basalt met with in the lower beds of the limestone are cemented to the parent-rock by a ferruginous sand stone, while the rock surface exhibits unmistakable signs of carbonation.

VI.—GROUNDS UPON WHICH THE OCCURRENCE OF PETROLEUM IN THE AREA UNDER REVIEW WAS BASED.

- (i.) The presence of Bitumen or Asphaltum on the beach.
- (ii.) Oil-like scum on the sea and upon certain inland waters.
- (iii.) So-called Bituminous Clay and Rock from the bed of the Warren River.
- (iv.) Coal Deposits at Fly Brook.
- (v.) Reports upon the petroliferous character of the District.
- (vi.) Evidence afforded by the bores.

INTRODUCTORY.—By way of introduction to this section it will not be out of place to quote from a recent report by Mr. E. H. Cunningham Craig, who is one of the recognised authorities upon the geology of petroliferous deposits. Mr. Craig was engaged by the Union Government of South Africa to examine and report upon their reputed oil deposits, and it is from his official report that the following extract is taken:—

It is evident that in South Africa petroleum has been “prospected for” just as if it were gold or diamonds, *i.e.*, by searching for “surface indications.” The surface indications chiefly noted were oils naturally distilled by the heat of intrusions, marshy gas, ferric hydroxide films, salt pans and various other phenomena even less pertinent. These so-called indications have led away the prospector from any chance of achieving the desired result; and considerable capital has unfortunately been sunk in propositions which never from the first had the remotest prospect of success, and which would never have been attempted had experienced scientific advice been obtained.

Whatever theory may be held as to the origin of petroleum, three points have to be considered, viz., (1) the presence of sufficient carbonaceous material from which oil can be formed; (2) the conditions of deposition; and (3) the geological structure. In a locality where these conditions are favourable, an oil field can be predicted with certainty. . . . The conditions of deposition necessary are a thick series of strata formed of alternations of porous and impervious groups of rock formation. The absence of igneous intrusions is also to be desired.

In his standard work entitled “Oil-Finding”* the same author, under geological structure, lays considerable emphasis upon

* Published by Edward Arnold, London, 1913.

the folding of the rocks, the dome formed anticline being the most favourable form for the occurrence of oil; generally speaking, an anticlinal fold is, in his opinion, almost necessary. From the above it will be seen that he attaches no importance to the so-called surface indications, which were introduced to his notice in South Africa, and since these were almost identical with those put forward by the prospector of the Warren River District, we can only presume that he would dismiss them in the same language.

(I.) THE PRESENCE OF BITUMEN OR ASPHALTUM ON THE BEACH.

From time to time after storms lumps of asphaltum have been washed up on the coast; no record, however, exists of it ever having been found inland up any of the river valleys or at the back of the sand-hills, but only in such positions along the seaward face of these hills to which it could have been thrown by the waves.

The prospectors stated upon the authority of old settlers that the material had been noticed on this coast for at least 20 years prior to 1901, from which it would appear that what was thrown up prior to this time was in such limited quantities as to have been mistaken for pitch dropped by passing vessels. This inference is supported by the fact that neither Mr. H. Y. L. Brown, who as Government Geologist visited this locality in 1872, nor Mr. E. T. Hardman, who as Government Geologist visited it in 1884, makes any reference to its presence on this coast.

It is quite evident that the statement that large quantities of bitumen are thrown up after each succeeding storm is quite erroneous, for when the present writer visited this coast in 1889 and again in 1902, bitumen was by no means plentiful, while in the last-mentioned year Mr. A. Gibb Maitland, the Government Geologist, states in his report upon this locality, "*No trace was seen by me of asphalt anywhere along the beach.*"

The following is an extract from the report by Mr. A. Montgomery, M.A., State Mining Engineer (Mines Department Annual Report, 1903, p. 97):—

The reason that has induced prospecting for oil in this neighbourhood lies in the frequent occurrence on the beach between the Lower Blackwood and Point D'Entrecasteaux of pieces of bitumen and asphaltum of very good quality, and as is well known this substance is very commonly found at surface where oil springs burst out on the ground, being formed from petroleum partly by evaporation of the lighter oils, and partly by "inspissation" (thickening), a molecular change due to the absorption of oxygen and sometimes to the action of light. The bitumen or asphaltum is commonly thrown up on the beach sometimes in quite large pieces, one being described as being as big as a piano case, and local residents have often made use of it for mending boats.* When first thrown up it is stated to be usually quite soft, smelling strongly of kerosene, but after exposure to the air for a time it becomes hard and brittle. While travelling along the beach from the mouth of

* There are no boats on this coast nor have there been, it being too exposed.
H.P.W.

the Warren River to Malamup, we found three pieces of it on the sand at about high water mark, between Meerup Brook and Malamup, and Mr. Brockman informed me that this was the part of the coast where, according to his experience, it was most commonly found. I could get no authentic information as to its ever having been found inland, though there is a rumour that it has been obtained also up the Blackwood River years ago.* If it can be estimated that the source of this bitumen is in this district, there would be every reason for persevering in prospecting for oil by boring. Being cast up on the ocean beach, however, there is no certainty as to where it has come from. It is pretty certainly submarine, however, and may lie some distance out from the coast.

The writer has recently visited and practically traversed the entire length of beach between Point D'Entrecasteaux and the Blackwood River without discovering a single piece of bitumen, although this was carefully sought for, while he was informed on very good local authority that little or none had been observed during the last five years.

Asphaltum is not confined to this section of the coast, but has been washed up on the beach at many points between Cape Leeuwin on the west, and the Murray Mouth, in South Australia, on the east, a distance of 1,500 miles, mention being made by Mr. H. Y. L. Brown, late Government Geologist of that State, of its discovery at the mouth of the Glenelg River. Kangaroo Island, Yorke Peninsula, Port Lincoln, and the Murray Mouth, at several of which localities considerable sums of money were expended upon boring.† He further states, as his opinion, that the occurrence of asphalt and similar substances on the coast is purely accidental, and that there is not the slightest evidence of their having been derived from local subterranean sources.‡

The late Ralph Tate, who was Professor of Natural History at the Adelaide University, in referring to the occurrence of asphaltum upon the coast of Kangaroo Island, South Australia, says:—

All circumstances conspire to prove that the substance is a waif upon these shores.§

Mr. L. Keith Ward, the present Government Geologist of South Australia, in a recent official report says that the presence of asphaltum on the shores is the main evidence adduced by the prospectors in support of their contention that petroliferous deposits exist upon Kangaroo Island and Eyre's Peninsula, upon which subject, in his concluding remarks, he says:—

It has been shown also that the freshest material available for examination has such a density that it will readily float in sea water, and that variations of density occur in a single specimen. The writer is therefore of the opinion that this asphaltum has been borne on the oceanic currents from some unknown source to the beaches on which

* This question was recently investigated by the present writer, when the substance proved to be a brilliant black lignite like the Fly Brook Beds.

† Record of the Mines of South Australia, 3rd Edition, 1899, p. 180.

‡ "Kangaroo Island" Report of the Govt. Geologist, South Aust., 1898. In this opinion he is supported by Dr. Wade. Bull. 4, Geol. Sur., S.A., 1915.

§ Botany of Kangaroo Island—Trans. and Proceedings Royal Society of South Australia, Vol. VI., pp. 128-9.

it is picked up. Perhaps this source is not far distant, perhaps it is remote; it certainly cannot be precisely indicated.*

Some samples were forwarded by Mr. Ward for comparison with those of this State, when chemical examination by Mr. Simpson proved them to be identical in composition, thus indicating very forcibly a common source (see Appendix I., p. 46).

The present writer examined and reported upon all of these occurrences while he was Assistant Government Geologist in South Australia in 1883-6, and has later examined and reported upon similar ones all along the South Coast of this State as far east as the Bight.

The extent of coast line on which asphaltum has been washed up therefore measures some 1,500 miles in length, or between E. Long. 115deg. and 140deg., over which area it is associated with a large assortment of other foreign substance such as pumice, teak, indiarubber, kauri-gum, and torbanite (kerosene shale), while it is always clean and free from sand, earth or other foreign substances with which it would be contaminated if it was exuded in the form of a spring on the beach, and this fact points to its submarine source.

Asphaltum in the pure state has a specific gravity which varies from 1.0 to 1.8, while sea water is 1.026; it is therefore quite clear that, given sufficient purity, it will float in the sea, which fact has been denied by the persons interested in the oil company, although they admit that the lumps of asphaltum are quite soft when first thrown up. In this they may be absolutely correct so far as their own observations go, but they have made no allowance for the change which takes place in the lumps of asphaltum after being cast up, due to the loss of the more valuable oils. It is generally admitted that when these lumps are first thrown up they are plastic, but upon exposure to the sun rapidly harden on the outside and crack, in which process it is only natural to suppose that a large proportion of the more lighter hydrocarbons are given off, thus increasing the specific gravity of the lumps. That these are not so much denser than sea water, even after partially drying, is clearly demonstrated by the specific gravity tests made by Mr. E. S. Simpson, Chemist to the Department (see Appendix I., p. 47).

It is generally acknowledged that the asphaltum occurs on the beach only, but the supporters of the Warren Oil-basin theory contend that it will not float and is therefore washed up from near the shore-line. If this was the case, however, we should only expect to find it between the Warren River and Cape Leeuwin, since the currents flow from east to west on this coast.

Mr. Göczel in his report suggests, as the origin of the lump-bitumen, the conglomeration of the oil-like scum to be mentioned in the following section.

* The Possibilities of the Discovery of Petroleum on Kangaroo Is., and the Western Coast of Eyre's Pen., Bull. 2, Geol. Sur., S.A., 1913.

It is generally admitted, even by the "oil experts," that this bitumen is only found on the beach, but they contend that its presence is due to exudation of bituminous matter from the outcrop of the Warren beds beneath the sea at a short distance from the coast; therefore the extension of these beds if tapped inland, should yield oil. On this point, however, the bores afford negative evidence.

It will be noticed all the so-called evidence of the presence of oil is based upon theories relative for the most part to the origin of the asphaltum which is the only petroliferous substance that has ever been found in this district. Where this comes from it is impossible to say, but since it is of such an exceptionally uniformly high-grade composition there can be little doubt but that all the asphaltum strewn upon the south coast of Australia originated from one common source.

An examination of an ocean current map will make it quite clear why its distribution is restricted to one section of the coast only, for it will be observed that the great southern current which flows in a north-easterly direction, bifurcates before striking the Leeuwin, one branch of which flows along the south coast of this continent, but again splits before reaching Tasmania, one half turning northward then westward, after striking Kangaroo Island it sweeps into the Bight and so on round Cape Leeuwin beyond which it again unites with the northward branch which flows into the Indian Ocean.

The conveyor of the asphaltum is therefore clearly the current which flows in a westerly direction from Kangaroo Island in South Australia, to Cape Leeuwin, round and up the north coast, along which one piece has been found as far north as Mandurah. The agency directly responsible for the deposition of this material on the beach is the south-westerly gales, which, striking this current obliquely, drive all the associated flotsam shorewards.

It will, therefore, be seen that the asphaltum, being purely a derelict of the ocean, cannot be regarded in the light of evidence favourable to the presence of petroliferous deposits in this district.

(II.) OIL-LIKE SCUM ON THE SEA AND UPON CERTAIN INLAND WATERS.

On this point very considerable emphasis was laid by the company promoters who forwarded samples for analysis both to their own chemist, Mr. S. S. Dougall, F.I.C., and to the Department of Mines. The former of these reported that the bottle contained a sample of sea-water which had a strong smell of sulphuretted hydrogen and yielded 27 grains of mineral oil per gallon, while he further stated that the dulness on the bottle was not due to the presence of oil, but was a frostiness on the outside of the glass. The other sample was handed to Mr. E. S. Simpson, B.E., F.C.S.,

Chemist to the Geological Survey, who reported that he was unable to detect the least trace of mineral oil in it.

The discrepancy in the above reports is possibly due to the fact that a bottle which had previously been contaminated with oil was used in the case of the sample handed to Mr. Dougall, a suggestion which is supported by his own remarks which clearly indicated that, in his opinion, an old dirty bottle had been utilised for the purpose.

Later on Mr. A. Montgomery, M.A., F.G.S., the State Mining Engineer, who examined this scum *in situ* under the guidance of the Company's representative, states * :—

I saw some slight iridescent scum on the Warren River and it was just as is common on any swampy stream, the scums on the ocean which were pointed out to me as similar to those which had been thought to prove the existence of oil had neither oily feel or smell, when thrown upon the beach, but were made up of dead marine organic matter.

Mr. Göczel advances the theory that this scum is a thin skin of crude oil which forms into small plastic particles after the loss of the volatile oils, while these particles unite by the churning action of the sea in a similar manner to the butter-fat in cream, thus forming plastic lumps which are borne shorewards by storms and thrown up on the beach in the form of asphaltum.

The scum upon the stagnant inland waters is of common occurrence on all swamps, and certainly resembles the appearance of a thin sheet of kerosene in that greasy iridescent appearance, but is easily distinguishable from any oily substance if disturbed, when instead of rapidly re-covering the surface of the water it breaks into ice-like plates which pile one upon another leaving intervening blank spaces. This substance has, on many occasions, been chemically examined in the Departmental Laboratory, when it proved to contain no oil, but to consist of ferric hydroxide due to surface evaporation of water-charged iron in combination with organic acids.

What the scum on the sea is has not yet been definitely determined, since the "oil experts" refer to a line of discoloured water lying some mile or so from the shore. To this they claim that one of their party swam and obtained a sample in a bottle and that it proved to contain petroleum. This statement has not, however, been authenticated since there are few people who care to risk such a swim in the possible presence of sharks, while there are no boats on this coast as the surf is too heavy.

The writer has observed this coloured line from the high coastal hills in calm weather when the wind was off shore, but since this was replaced by a line of breakers in rough and south-westerly weather it may surely and with more reason be attributed to weed-covered reefs.

* Annual Report, Department of Mines, 1903.

This scum question is closely associated with the kerosene-tasting water reported on several occasions and confirmed by Mr. Göezel; samples, however, have not yet been forwarded to the Government or the position of the locality reported so that it may be officially investigated; consequently little credence can be attached to these statements. The presence of this oil-like scum, which contains no oil, cannot therefore be regarded as an indication of the presence of petroleum in this district.

(iii.) SO-CALLED BITUMINOUS CLAY AND ROCK FROM THE BED OF
THE WARREN RIVER.

This was considered as one of the most important indications of the presence of oil-bearing beds, and consequently the first prospecting area was pegged out so as to include it, while samples were forwarded both to Mr. Dougall and the Geological Survey for examination.

Upon the sample submitted to him, Mr. Dougall reported that after drying the "Bituminous clay" at 212deg. F. it yielded 7.26 gallons of oil, but the quantity of clay from which this was obtained is not mentioned.

Two samples were submitted to Mr. Simpson; of the first, described as "Bituminous Rock" from the mouth of the Warren River, he states that:—

It contains only the merest trace of bitumen such as can be found in all organic products. It is in no sense of the term "bituminous rock," but rather a carbonaceous sandstone with a composition of:—

Moisture	..	..	..	..	..	..	1.13
Bitumen	..	..	..	..	..	..	.01
Non-bituminous organic matter	..	..	..	..	..	..	5.93
Earthy matter	..	..	..	..	..	..	92.93
							100.00

The second sample is described as Bituminous Clay three and a-half miles from the mouth of the Warren River. Of this he states:—

This sample consists of peat and is not in any way bituminous. The mere fact that oil can be obtained from a mineral or rock by destructive distillation is no criterion of the presence in the rock of petroleum or bitumen and therefore no reason for labelling the rock "bituminous." All organic matter, wood, coal, animal matter, etc., will yield oil in more or less quantities on distillation. Both these samples will do this, but are not on that account to be called "bituminous rock" since they contain no petroleum and only an inappreciable amount of bitumen (mineral organic matter soluble in carbon bisulphide). They are no indications of the presence of mineral oil in the locality.

At first sight it appears that Messrs. Dougall and Simpson differ, but upon looking more carefully into the reports it will be found that this is not the case, since the former only determines the quantity of oil that could be obtained, by destructive distillation,

which is fully admitted by the latter, but who states further that this does not consist of petroleum.

The present writer examined these deposits in 1902, at the time they were being prospected, and found them to be sandy, peaty deposits similar to those so commonly met with in the swamps along the south coast.

These deposits are always met with at those places where the vegetation is dense, which would not be the case if any mineral oil was present, since such oil is poison to all plant life, therefore these deposits may be disregarded as evidence of the presence of petroleum.

(iv.) COAL DEPOSITS AT FLY BROOK.

The following is a description of this formation, mostly taken from the present writer's report written in the year 1889, at which time boring operations were in progress, with the object of testing these measures.

In the year 1888 a number of leases were taken up for coal upon the Fly Brook, which is a branch of the Donnelly River. A number of bores were put down by hand, the deepest of which was 128 feet, and this passed through no less than 17 seams of coal aggregating 20 feet in thickness. The largest of these seams measured five feet four inches in thickness, but had a six-inch clay parting; the next largest was two feet four inches with a three-inch parting, and another two feet three inches with a two-inch parting.

It is a lustrous black coal, having a subconchoidal fracture resembling jet but lacking its hardness, while woody structure is clearly visible on the weathered surface. It is a very light hydrous coal which rapidly falls to pieces upon exposure to the air. It is almost identical in composition with certain Cretaceous coals on the Pacific coast of North America.

The following is a comparative table giving the average composition of this coal with those of Collie and New South Wales:—

PROXIMATE ANALYSIS. *

—	Fly Brook.	Collieburn.	Collie Proprietary.	N.S.W.
Water	14·51	13·81	12·39	2·22
Volatile Matter ..	37·89	36·16	26·79	29·94
Fixed Carbon ..	44·89	45·19	52·01	58·99
Ash	2·71	4·84	8·81	8·85

* Air dried samples.

From the above it will be noticed that this coal has a striking similarity to that from Collieburn, which lends colour to the contention that these beds are in all probability the southern extension

of the Donnybrook series which are possibly the upper beds of the Collie series.

It is a hydrous non-caking variety of coal, being too tender and air slacked too rapidly to be suitable for transport.

ULTIMATE ANALYSIS.

—	Fly Brook.	Collieburn.	Collie Proprietary.	N.S.W.
Carbon	64·91	69·44	70·56	76·42
Hydrogen	5·03	4·65	3·86	5·47
Oxygen	24·99	18·10	13·74	7·49
Nitrogen	·62	1·42	1·31	88
Sulphur	·43	·77	·55	1·13
Ash	4·02	5·62	9·98	8·61

From this it will be seen that although it contains a smaller percentage of carbon and a higher percentage of oxygen than the Collie coals, they are undoubtedly of the same class and quite distinct from the New South Wales coals.

The coal-bearing series consists of sandstone, grits, and clay beds (the latter being often micaceous) the whole being overlaid by a bed of conglomerate (often ferruginous), containing large water-worn pebbles of quartzite, quartz, and other crystalline rocks, which latter formation is met with all along the Darling fault between the Warren and the Blackwood Rivers. Basaltic outcrops have also been met with at one or two points over this area, but whether these exist in the form of flows, sills or dykes is at present uncertain, and further the relative age of this series has not as yet been determined.

In the No. 3 bore put down on the Warren River by the Oil Corporation, 500 feet of these measures were passed through, but only small seams of coal were encountered. Comparatively little stress was, however, laid upon this Fly Brook Series by those interested in oil, probably owing to the fact that a sample of this coal was forwarded by the prospectors to Mr. Dougall, who dismissed it with the curt remark that—

The sample submitted to me was not a true coal but a lignite.* Any way, it is very superior to the so-called "Bituminous Shale," and would have yielded far more oil if treated under similar conditions.

(v.) REPORTS UPON THE PETROLIFEROUS CHARACTER OF THE DISTRICT.

The reports written upon the petroliferous possibilities of this area may be classed under two heads, the first being by those

* Report by Mr. S. S. Dougall, dated 30-11-01, G.S. File, 17/02.

of the directly or indirectly interested parties, and the second by disinterested Government officials. The first may be again divided into two groups, viz., favourable and unfavourable; to the first of which very considerable prominence was given by the press since reports of this character formed pleasant reading to the majority because they coincided with their wishes.

The present writer was one of the interested persons whose report was not favourable, as he did not feel justified, after making a careful examination of the district, in advising the Company whom he represented to expend any money upon further tests. His report being one of the few of an adverse character published, was most unmercifully treated by persons of the other way of thinking, whilst the disinterested reports of the Government Geologist received little less severe handling.

Amongst the favourable reports the one to which most weight was attached is by Mr. S. Göczel, formerly Field Geologist to the Government, but at the time in the employ of the Oil Corporation. He prepared a pamphlet in which he states that the geological formations were not only distinctly favourable to the occurrence of oil, but that they are similar in many ways to those where oil was known to exist in other parts of the world. Unfortunately, however, the present writer can only join issue with him upon one point, viz., the presence of the Darling Fault; but Mr. Göczel's arguments with regard to the influence exercised by it upon the deposition of oil it is difficult to follow.

Since the presence of anticlinal folding in the rocks is a recognised feature of a typical oil basin, he naturally sought for indications of the presence of this stratigraphical feature in this District. Of this he satisfied himself, drawing his conclusion from the false bedding exposed in the cliff faces of the coastal sandstones. With regard to this point Mr. Montgomery says * :—

Mr. Göczel considers that there was a distinct anticlinal fold in the strata, and I was myself disposed to agree with him on that point until I had examined the larger sections presented at the mouth of the Meerup Brook, Warren River, and more especially the Donnelly River."

Both Messrs. Montgomery and Göczel consider these coastal sandstones to be the outcrop of beds of sedimentary origin having a general dip towards the range, but this notion was completely upset by the evidence afforded by the 1,700 feet bore, which although put down at a point two miles from the coast and well within the area covered by this formation, only passed through 80 feet of incoherent sand before entering the Donnybrook series,

* Annual Report, Mines Department, 1903, p. 96.

in which it continued to a depth of 550 feet, beneath which to the bottom only granitic grit was encountered.

These calcareous false-bedded sandstones are clearly only local superficial deposits representing old sand-dunes, the grains in which have been cemented by the lime contained in the intermingled shelly matter, while the very uniform dip is due to the direction of the prevailing winds. This formation has been examined by the writer, who found it to form practically one line of coastal hills extending from Geraldton to Cape Leeuwin, and from the latter point to Albany. Any doubt as to the origin of these beds can be easily set at rest by examining the sections exposed at Fremantle and Mount Eliza on the Perth-Fremantle Road, in the Metropolitan Area.

Mr. Göczel makes the statement that he found numerous fossils in this formation, and particularly mentions some Saurian remains; therefore, as these are of a particular interest, the writer spent a considerable time upon a careful search for these without result. It is a noticeable fact that Mr. Göczel has never been able to produce specimens of these Saurian bones, nor later on of those he claimed to have found in the so-called phosphatic caves on the coast to the northward of Perth, nor in this case either has anyone else been able to obtain any of these rare fossil remains.

It is quite impossible for anyone to construct a section of this area with any certainty of accuracy, since the only rocks exposed consist of false-bedded calcareous sandstones of the coastal hills and outcrops of basalt; therefore, the only evidence we possess with regard to the underlying strata is furnished by the bore record which proves conclusively that the strata passed through is quite unfavourable to the presence and storage of oil deposits since there are no thick impervious beds covering a previous stratum which might form an oil reservoir and restrain it from finding its own way to the surface.

It may be argued on the other side that there are flows of basalt, but leaving out of the question the doubt as to whether these are really of any considerable extent, they are not looked upon with a favourable eye by persons of considerable experience in oil finding and are excluded by such a recognised authority as Mr. Cunningham Craig from the possible causes of oil deposits. Mr. Göczel, however, attaches considerable weight to the presence of this rock, which he takes considerable trouble to demonstrate was intruded in a sheet form into the coastal sandstone beds, where it is clearly an old reef upon which the sand-dunes have been piled. He also mentions the occurrence of basaltic rock at several localities at which the writer failed to find it, while samples of the only rock outcropping at these localities were collected, and determined by

Mr. Farquharson (see Appendix II., p. 49) as [13713] Amphibolite. [13710] Dolerite, and [13714] Quartz porphyry.

Mr. Göczel also considers the ironstone gravels (laterite) to be of basaltic origin and the one-time scoria, lapilli and ash of basaltic eruptions from which lime was leached and carried to the sea where it caused great activity amongst the coral polypi which built up the coastal limestone hills. Unfortunately for this beautiful romance the origin of these lateritic deposits is perfectly well understood, but this need not be discussed here.

Mr. Göczel also advances a theory to account for the presence of bitumen on the shore, but since this has been referred to under section ii., the same ground need not be traversed here, but its adoption cannot be recommended owing to its improbability. The report naturally carried very great weight owing to Mr. Göczel's former official position; it has, therefore, been rather fully dealt with as it was upon this report principally that the investors built their hopes, while it has been used again and again with the object of resurrecting this question.

A large number of reports, written by self-created oil experts were published in the local Press. These naturally assisted in arousing public excitement, but since the statements made in them are destitute of fact it is needless to more than consider them generally. Unfortunately certain of these have been accepted as credible by Mr. J. E. Carne, the Assistant Government Geologist in New South Wales, who, in his memoir on the Kerosene Shale deposits of that State, while reviewing the possibilities of the discovery of oil in this State, compares the unfavourable character of the report on the Warren River District, by Mr. Maitland, the Government Geologist (with those appearing in the Press), by saying:—

As the reports, however, are so circumstantial, and supported to some extent by the undoubted occurrence of asphaltum, and backed by the investment of capital, it has been deemed wise to insert some of the most substantial with the authorities for them.

He then proceeds to quote a number of newspaper extracts furnished to the Press by the promoters of the Company. The text of this is given under the heading of Previous Literature, page 9.

Leaving aside the question of the very unprofessional attitude adopted by Mr. Carne in casting a doubt upon the pronouncement made by an officer of another State it may be pointed out that since he has not inspected the areas in question he cannot be qualified to express an opinion one way or the other; while, further, by quoting certain reports which were not founded on fact he has made these authoritative.

Again recently while giving evidence before the Interstate Commission sitting in Melbourne, on the Shale Oil Industry, he is credited, according to the daily press, with making the following definite statement in referring to Western Australia:—

Still I don't consider that the possibilities have been exhausted. One bore in Western Australia passed through a 3-inch seam of bitumen. This statement Mr. Carne has since admitted, in a letter to this office, was from hearsay evidence.

This unqualified utterance was, however, seized with avidity by the local Press and published in the leading daily paper * under the heading "Geologists differ," which might be taken to cast a doubt upon the reliability of the work of the officers of the Department.

That this statement should have been published by Mr. Carne, who is recognised as an Australian authority on kerosene shale and coal deposits, is most unfortunate since considerable capital can be made out of it by unscrupulous people, and it may be used by them to throw discredit upon official reports prepared by officers whose only desire is to state the actual facts and protect the unsuspecting.

Upon 14th April, 1904, an article appeared in the *Morning Herald* with reference to a comparative diagram that was on exhibition at the offices of the Westralian Mining and Oil Corporation, which demonstrated conclusively that the strata passed through at the Warren was identical with that in the two famous "gushers" in Texas, known as the Higgins and Lucas bores. The article states:—

The general resemblance between the Higgins, Lucas and Warren bores at various levels displayed in the diagram is very striking. For instance, at 200 feet all three have coarse sand and gravel. At 400 feet all three have pebbles and sand, succeeded by lignite. Gas appears in two at about 700 feet. In all three calcareous sand and clay and carbonaceous matter underlie this level. In both Higgins and Lucas wells oil was yet obtained at a little over 1,000 feet below the surface. The greater depth yet attained by the boring rods at the Warren River is 917 feet. At this point the sand is impregnated with sulphur. In the Higgins well this was the feature encountered for the first time at a slightly lower level, and immediately underlaying the hard sulphur rock which formed the enclosing dome of the oil reservoir. (See No. 3 Bore Section, p. 34.)

This is the typical class of so-called evidence put forward by the Company's "Oil Experts" with the object of inducing the general public to speculate their money in this venture and the Government to subsidize them.

As was afterwards proved by boring to a depth of 1,700 feet these so-called indications (if they existed) were absolutely un-

* "West Australian," April, 3rd, 1914.

reliable since nothing but detrital matter formed from the wash-off of the hills was encountered. It has been truly stated that in boring for oil, without the bore is penetrating known oil-bearing strata, there are no such things as "favourable indications," this term being used for Company promotion purposes only.

All the official reports were without exception unfavourable. A resumé of these will be found in that portion of this *Bulletin* under Previous Literature. The great economic importance attaching to the presence of oil deposits and the reputed fortunes made from this source was, of course, responsible for the appearance of the "oil expert" in this State directly the rumour spread abroad that indications existed, and these gentlemen are responsible for a large number of reports which, although of no real value, were eagerly accepted by the readily gullible public whose only desire was to get rich quickly.

(vi.) EVIDENCE AFFORDED BY THE BORES.

No. 1 Bore, which is located upon the east bank of the Warren River about six miles from the mouth, is situated too close to the Darling fault to be of any informative value. This bore is stated to have passed through 49 feet of sand and then 32 feet of basalt, but no samples of the latter were forwarded to this office, nor are they to be found on the surface at the bore-site.*

No. 2 Bore is situated about half a mile farther south still close to the same fault line. This was put down to a depth of 504 feet in drift sand and then abandoned†

About this time Mr. Göczel visited this field on behalf of the Company, to whom he furnished a report. While in the district he recommended them to discontinue boring operations in such proximity to the fault-line and selected a site, called No. 3, situated in the sand-dune area about two miles from the mouth of the Warren River upon its western bank. About 700 feet of this bore was put down by the Company, whilst the balance of the 1,700 feet was subsidised by the Government at the rate of £2 for £1 expended.

From the first 195 feet no cores were forwarded to this office, while no Government supervision was exercised until the subsidised portion of the boring was commenced. The Department is, therefore, entirely dependent upon the bore journal for the first 195 feet, and this is of little value if one is to judge from the description of the strata passed through, as shown in the bore journal of the next 500 feet compared with the determinations of the cores forwarded to the Department.‡

*This was possibly detrital matter from amphibolite rock [13713] which outcrops close by.

† Ann. Rept., Geol. Survey, 1902, p. 15.

‡ Ann. Rept., Geol. Survey, 1914, p. 19.

NO. 3 BORE, WARREN RIVER.

Depth feet.	Mr. Nankivell's Determinations.	Depth. feet.	The Government Geologist's Determinations.*
0-80	Incoherent sand	..	No sample submitted.
80-100	Black clay with coal seams	..	do.
100-110	Quartz pebbles	..	do.
110-162	Incoherent sand	..	do.
162-183	Basalt partly decomposed	..	do.
183-185	Shale and Brown Coal	..	do.
185-195	Bituminous sandstone	..	do.
195-205	Brown coal with ashes, mud, pumice, and graphite	195-205	Micaceous shale with plant remains.
205-265	Scoriae from pyrites, sand, mica, clay, graphite and gas (Artesian Water)	..	No sample submitted.
265-267	Quartz pebbles and iron pyrites	..	do.
267-285	Decomposed basalt (some gas)	..	do.
285-315	Hard basalt	..	†
315-317	Calcite	..	do.
317-322	Volcanic matter, black mud and bitumen	317-322	Debris of black shale.
322-331	Sand, charcoal, and decomposed basalt	..	No sample submitted.
331-340	Brown shale, pieces of shale, iron pyrites and anthracitised matter	..	do.
340-341	Quartz and pebbles	..	do.
341-349	Pumice, mica, and graphite (Artesian Water)	..	do.
349-370	Sand, scoria, ashes, coal particles, graphite and salt (Artesian Water)	..	do.
370-371	Graphite with cementing material of the nature of lye	..	do.
371-477	Dry sand	..	do.
477-502	Quick sand	492-503	Sand with fragments of dark shale.
502-590	Sand with garnets and mica	503-512	Micaceous somewhat sandy shale with pieces of grit and quartzite.
		512-550	No sample submitted.

555	Coal particles	553—570	Coarse angular sand of quartz felspar with pale garnets and fragments of pyritous shale.
		570—597	Fine angular sand of quartz felspar and mica.
		597—640	No sample submitted.
590—730	Alternating fine and coarse sand, slight flow of artesian water (saline)	640—652	Fine angular sand of quartz felspar and pale garnets.
		652—680	Angular sand of quartz felspar and mica with few pale garnets.
690	Anthracite particles below this depth	680—705	do.
		705—720	Coarse angular sand of clear transparent quartz and white felspar.
730—733	Calcareous sandstone with coal, anthracitised lignite, fire clay, and gas, artesian water (fresh)	720—722	Fine angular sand of quartz felspar and little mica.
733—760	Fine-grained sandstone	722—729	No sample submitted.
760—860	Sand with traces of fossil shells and anthracitised lignite	729—736	Fine-grained sand of quartz felspar and mica with a little carbonaceous shale.
		736—761	do.
		761—890	No sample submitted.
860—900	Fine-grained calcareous sandstone	890—900	Coarse angular quartz sand with little felspar and pale garnets.
900—917	Fine-grained calcareous sandstone, sometimes coarse No determinations below this depth	900—910	Very coarse angular sand of quartz and felspar.
		910—935	Fine angular sand of quartz, felspar, with little mica and pale garnets.
	Do.	935—952	Fine angular sand of quartz felspar and mica.
	Do.	952—1,120	Coarse angular sand of quartz and felspar.
	Do.	1,120—1,130	Coarse angular sand of quartz and felspar with little mica.
	Do.	1,130—1,138	Coarse angular sand of quartz and felspar with few garnets.
	Do.	1,138—1,160	do.
	Do.	1,160—1,163	Fine micaceous and somewhat sandy shale.

* These core samples are still in the possession of the Survey.

† Some fragments marked "portions of cores from lower flow of basalt," presumably from between 285 ft. and 315 ft.; these are not basalt but mud-stone.

NO. 3 BORE, WARREN RIVER—*continued*.

Depth feet	Mr. Nankivell's Determinations.	Depth, feet.	The Government Geologist's Determinations.
No determinations below this depth	..	1,163—1,305	Coarse angular quartz and felspar sand and gravel.
Do.	..	1,305—1,340	Fine white quartz sand.
Do.	..	1,340—1,490	Coarse angular quartz felspar sand and gravel.
Do.	..	1,490—1,560	Coarse granular quartz felspar sand and gravel, with few small pale garnets.
Do.	..	1,560—1,600	Fine quartz sand.
Do.	..	1,600—1,670	Coarse angular quartz felspar sand.
Do.	..	1,670—1,710	Fine quartz sand.
Do.	..	1,710—1,719	Coarse quartz sand with a little felspar.

From the preceding table it will at once be apparent that the Company did not forward to the Government Geologist for determination any of the core from those sections of the bore to which importance was attached as indicative of the presence of an oil-bearing stratum, while the determinations of those forwarded are so unreconcilable with those of the Company as to cast a doubt upon the whole section prepared by them.

It seems strange that no basalt, anthracite, graphite, bituminous shale, volcanic mud, ash, scoriae, or pumice, could be detected in any of the cores submitted: the basalt in particular, which is stated to have been 30 feet in thickness and hard, would most certainly have been recognised if forwarded to this office.

It is true that one odd sample was forwarded by the Secretary of the Company, marked "from level basalt flow" but this consists of a brown clayish pyritic nodule and a black and white veined mudstone.

It is evident, however, that in the first 500 feet the Fly Brook Series were passed through, while below that depth the whole consisted of granitic material, clearly derived from the wash-off of the Darling Range, the only variation being in gradation of the particles, but not of the materials which always occur as a mixture of angular grains of quartz, felspar, garnet and mica.

This boring proved two things: 1st, that no oil existed in the locality bored, and 2nd, that the formation was not of the character favourable for its occurrence, while a comparison of the tables of strata passed through proves that the records as issued to the investors were misleading.

VII.—CONCLUSIONS.

SUMMARY.—After a careful examination of all the evidence adduced in favour of the existence of petroliferous deposits in this district, both in the office and the field, the conclusions arrived at are as follow:—

(1.) The occurrence of asphaltum upon the beach affords no evidence of the existence of petroliferous deposits in the district, since it is evidently a foreign substance thrown up by the sea, a view supported by the facts of (a) its extensive distribution on the southern coast of Australia (over 1,500 miles), (b) its occurrence upon the beach and never inland, and (c) its association with other foreign flotsam and jetsam.

(2.) The presence of an iridescent scum upon the sea and upon inland waters proves only to be ferric hydroxide films resulting from the decomposition of bicarbonates of iron, which, although bearing a strong resemblance to petroleum scum, differ from it (a) in that it does not possess the characteristic smell, and (b) when disturbed it does not rapidly close over as the oil does, but breaks

into floating ice-like scales which pack one upon another leaving intervening clear water.

(3.) The so-called bituminous rock only proves to be peaty deposits destitute of petroleum. The outcrops of petroliferous deposits, or areas where exudations from them occur, are always practically destitute of vegetation; therefore, there are no indications of these in this district, which is densely covered with either timber or scrub.

(4.) The Fly Brook coal deposits fulfil the condition as laid down by Mr. Cunningham-Craig in "The presence of carbonaceous material from which oil can be formed," but since this is not supported by other necessary conditions it is by itself of no more value as an indication of the presence of oil than is the occurrence of coal at Collie.

(5.) The evidence afforded by the bore is not only inconclusive but positively negative, since neither was any formation cut which in any way indicated the presence of petroleum, nor were the beds arranged in such order nor apparently deposited under such conditions as to warrant in any way the supposition that they would be associated with oil-bearing measures. While further, at a little below 500 feet, an angular granitic grit, destitute of organic matter was met with which continued down until boring operations ceased at a depth of 1,719 feet.

(6.) As no stratified rocks are found outcropping in this district, it is quite impossible to construct a really reliable geological section, while all the surface evidence points to the conclusion that a fairly horizontal series of sediments, probably of lacustrine origin (the Donnybrook Series) underlie the entire plain to the westward of the Darling fault, from which they extend until another granite outcrop is encountered on the eastern side of the Leeuwin-Naturaliste ridge, while in a southerly direction it extends beneath the Coastal Plain (more recent lagoon) and the ancient and modern dunes to the South Coast. The only dislocation (beyond probably minor faults) being due to the intrusions of the basaltic sheets or dykes.

The writer was unable to find any evidence of the anticlinal and synclinal folding of strata nor fossil remains, referred to by Mr. Göczel.

CONCLUSION.—It may be here stated with confidence (a) that there are absolutely no indications of petroliferous deposits *in situ* in this portion of the State, (b) that the geological formations are in no way favourable to such, and (c) that the entire mass of so-called evidence adduced in favour of the existence of such deposits appears to be directly traceable to either company promoters or other interested persons in their employ.

The reports by these persons have been widely circulated and have carried conviction to the minds of a very large section of the population in the State, who consequently are firmly convinced that a petroliferous area of considerable extent and promise exists in the district to which this report alludes.

So firm, in fact, is this conviction that the adverse reports of the Government officers have failed to shake it, since the latter, not posing as "oil experts," are supposed to be wanting in a knowledge of the requisite and qualifying geological conditions governing the occurrence of mineral oil.

APPENDIX I.

ASPHALTUM FROM THE SOUTHERN COAST OF AUSTRALIA.

By

EDWARD S. SIMPSON, B.E., B.Sc., F.C.S.

For many years past hopes have been raised from time to time of the occurrence of petroleum along the southern coast of Australia, owing to the discovery, or re-discovery of detrital fragments of various substances, considered, with more or less reason, to be derivatives or sources of petroleum. The chief of these substances are asphaltum,* elaterite (coorongite, mineral caoutchouc), waxes, resins, "kerosene shale" (torbanite), brown coal, carbonaceous (coaly) shales, and the so-called "dung-bitumen."† Of these the asphaltum, waxes, kerosene shale, and resins have always been found on the ocean beaches or in close proximity thereto; the coorongite, in or near swamps, both close to and at a distance of some miles from the coast; the brown coal and coaly shales, *in situ* in river banks or low cliffs round lagoons, etc.; the "dung-bitumen" invariably at some distance inland from the sea in or near caves.

Whilst there is much doubt as to there being any connection between the majority of these substances enumerated, and the occurrence of petroleum, there can be no doubt whatever of the very close association of asphaltum with petroleum deposits. Thus G. H. Eldridge says, in an article on the "Origin and distribution of asphalt and bituminous rock deposits in the United States‡ :—

The origin of the (solid and semisolid) hydrocarbons and bituminous compounds may be traced, the writer believes, to petroleum. . . . The asphaltic earths, and solid bitumens in part, are frequently associated with active petroleum springs, or are found in regions renowned as oil-producing . . . The asphaltites and closely associated hydrocarbons can hardly have been derived otherwise than by the draining of petroleum pools or strata richly saturated with oil.

Redwood and Holloway, the leading authorities on petroleum, say § :—

Asphalt, or asphaltum, and asphalt rock are found widely distributed, and occur in some localities in immense quantities. . . . Asphalt is usually regarded as having resulted from the combined action of evaporation and atmospheric oxidation upon liquid petroleum as it issues from outcropping strata.

* The term "asphalt" is so frequently applied to artificial compounds containing coal-tar, etc., that most writers prefer the term "asphaltum" for the natural solid and semi-solid bitumens, which are soluble in carbon bisulphide.

† Insipissated rain-water extract of beds of marsupial and bat guano. It is like asphaltum in outward appearance, but is almost wholly soluble in water.

‡ United States Geological Survey Bulletin 213.

§ Redwood and Holloway, A. Treatise on Petroleum, p. 218.

A more recent writer, E. H. Cunningham Craig, says, under the caption "Indications of Oil" * :—

Surface indications are of various kinds according to the class of oil, the nature of the strata, and the geological structure. They comprise:—

- (a.) Seepages of oil.
- (b.) Asphalt deposits,
- (c.) Etc., etc.

Oils of asphaltic base nearly always make their presence obvious, when conditions are favourable, by more or less extensive deposits of asphalt along the outcrops of the petroliferous strata. There is, of course, no hard and fast line between a seepage of crude oil and a deposit of asphalt; every gradation of sticky and inspissating oil between the two may be observed on the same outcrop.

Finally, A. Beeby Thompson, writing in 1910, after referring to asphalts in general as representing natural seepages of petroleum, says † :—

Recent geological work in Trinidad has conclusively established the origin of the (pitch) lake as the outcrop of a well-defined petroleum-bearing stratum, and the present pitch is nothing more than the accumulated unevaporated residue of millions of tons of petroleum which have exuded for ages from these oil sands.

There can be no shadow of doubt, therefore, that asphaltum is not merely an indication of oil of the same type, as, for instance, galena is of silver or pyrites is of gold, but it is actually proof positive of the present or past existence of petroleum, since it is the remnant of petroleum which has risen to the surface or near to it. Asphaltum was originally an essential constituent of an asphaltic petroleum but was less volatile, or more easily converted into non-volatile compounds by the atmosphere, than its associates. Whatever may be the ultimate source of petroleum, petroleum itself is certainly the immediate source of asphaltum.

Petroleums are in all cases mixtures of very many hydrocarbons and other related bodies, and the crude oils from different localities vary very widely in the nature and proportions of their constituents. Two main types of crude oils are very generally recognised, viz. ‡ :—

- (a.) Asphaltic oils, yielding on slow distillation a dark asphaltic residue.
- (b.) Paraffin oils, yielding similarly a residue of light-coloured solid paraffins (wax).

Rarely do crude petroleums of either class contain any considerable proportion of the other class. Asphaltic oils may contain anything from 1 per cent. (Sumatra) up to 50 per cent. (California) of asphaltic material as obtained on slow evaporation. It is evidently such oils which yield natural asphaltums on reaching the surface through natural fissures in the rocks overlying the subterranean oil reservoir.

* E. H. Cunningham Craig, *Oil Finding*, p. 89.

† A. B. Thompson, *Petroleum Mining*, p. 108.

‡ A. B. Thompson, *Petroleum Mining*, p. 136.

TERMINOLOGY.—Asphaltum is known under a variety of terms some of which refer to particular types of asphaltum, whilst others are used by different writers to include not only asphaltum but other carbon compounds, artificial or natural. The chief of these terms are:—

Asphaltum.—The pure natural mixture of solid or semi-solid black carbon compounds which are completely soluble in carbon bisulphide.

Bitumen.—A term sometimes used as synonymous with asphaltum, but often applied to other similar looking natural carbon compounds not completely soluble in carbon bisulphide.

Pitch.—Originally applied to the true fluid or semi-fluid asphaltums of the "Near East," and also very often used for the earthy asphaltum of Trinidad. Now used also for the artificial products obtained from the distillation of coal tar and wood tar, which differ essentially from asphaltum in containing a large proportion of combined oxygen.

Glance Pitch.—The hardest and most brittle kind of asphaltum.

Maltha.—Fluid or semi-fluid asphaltum.

Asphalt.—Sometimes used as synonymous with asphaltum, but properly restricted to artificial or natural mixtures of minor proportions of asphaltum or pitch with earth or rock. The well-known Trinidad substance, which contains about 30 per cent. of earthy matter, may be looked upon as a low grade "asphaltum" or a very high grade "asphalt."

Manjak, grahamite, albertite, gilsonite, and tabbyite are all more or less distinct varieties of asphaltum.

COMPOSITION AND PROPERTIES OF ASPHALTUM IN GENERAL.

Asphaltum is a pure black substance which may be either solid or semi-fluid in consistency at the ordinary atmospheric temperatures. The semi-fluid varieties become less plastic and ultimately solid on long continued exposure to the air. Solid asphaltum is brittle and, when pure, breaks with a conchoidal fracture and brilliant lustre. When impure from the presence of appreciable amount of earthy matter or non-asphaltic (non-bituminous) organic matter such as leaf mould, the colour may be brownish, the fracture less typical, and the lustre duller. At varying temperatures a little above or below that of boiling water, asphaltums melt. They all ignite readily and burn with a smoky flame. The specific gravity of the purest types varies from 0.9 to 1.1, the more fluid varieties being the lighter, and the specific gravity rising on exposure to the air owing to loss by volatilisation of the lightest liquid constituents.

The exact chemical composition of asphaltum has never yet been completely determined, and it is certain that it varies in various localities. It is known, however, that no asphaltum is a

simple compound, but that all the substances known by this name are complex mixtures of simple hydrocarbons of many series with organic sulphur and nitrogen compounds. Oxygen is typically very low in amount as is also nitrogen. In the softer asphaltums some of the constituents are liquid, some solid. The ultimate composition, that is the total proportions of the elements carbon, hydrogen, sulphur, nitrogen and oxygen, has been determined in several cases, but not in the case of the Australian asphalt.

Broadly speaking, the purer asphaltums contain, on the average:—

Carbon	..	..	..	80 to 85 per cent.
Hydrogen	..	..	..	9 to 12 per cent.
Sulphur	..	..	..	1 to 10 per cent.
Nitrogen	..	..	..	Under 1 per cent.
Oxygen	..	..	..	Under 1 per cent.

The usual analysis made of an asphalt is known as a "proximate analysis," that is, an analysis into groups of related substances soluble in the same liquid, or volatile under the same circumstances. Two such methods of analysis are employed. In both cases the total earthy matter is determined by burning off all the carbonaceous matter, and the latter is sub-divided into bituminous (asphaltic) organic matter soluble in carbon bisulphide, and non-bituminous (non-asphaltic) organic matter insoluble in that solvent. At this stage the two methods diverge in their manner of again sub-dividing the bituminous matter. The two methods are:—

(a) *Endemann's Distillation Method*.—The asphaltum is distilled slowly at a temperature not rising ultimately above 235deg. Centigrade, and the weight of volatile oils (so-called petrolene) is determined. The non-volatile bituminous matter is called asphaltene. The total bituminous matter is thus divided up into petrolene and asphaltene.

(b) *Linton's Extraction Method*.—The asphaltum is subjected to the solvent action of petroleum spirit of specific gravity 0.65-0.67 until all soluble matter is extracted. The loss of weight is then determined, and the bituminous matter thus sub-divided into a part mainly liquid, soluble in petroleum spirit and sometimes called malthe, and a part, completely solid, which is soluble in carbon bisulphide but insoluble in petroleum spirit, sometimes called carbene. This method is that which has been applied to the Australian asphaltums.

Although the proportion soluble in petroleum spirit is, in every case, very different to the proportion volatilised below 235deg. C., yet, unfortunately, the terms petrolene and asphaltene have also been often wrongly applied to the fractions obtained by Linton's Method. This has led to serious errors in the interpretation of

analytical results. As an example of the scale of error possible, a Mexican asphaltum yielded:—

Endemann's Method, True Petrolene	26.51 per cent.
Linton's Method, Soluble in Petroleum Spirit (wrongly called Petrolene)	 87.12 per cent.

In every case the three common impurities—water, earthy matter, and non-bituminous organic matter (rotten vegetable matter etc.)—are estimated.

In Table I. are given analyses by Linton's Method of typical asphaltums and related substances from noted localities in various parts of the world.

COMPOSITION AND PROPERTIES OF ASPHALTUM FROM THE SOUTH COAST.

All the specimens of asphaltum collected at various times along the south coast of Australia from Cape Leeuwin on the west to Cape Otway on the east, appear to be of the same general type.

In the first place they are very pure asphaltum, the total impurities never exceeding two per cent. Externally they appear as rounded masses from about three to eight inches in diameter, rarely much larger, with a corrugated surface marked by occasional deep fissures.* They are jet black in colour with a conchoidal fracture when hard, and a brilliant lustre. The smaller fragments which have been exposed to the air for many years are quite solid throughout, though the centre is still soft enough to be marked by the pressure of the finger nail. Larger pieces from the sea shore have a hard surface layer, but in the centre of the mass the material is plastic. In the single case of the material dredged from the bottom of Albany Harbour the masses when fresh were almost wholly plastic or semi-fluid. In the accompanying Table II. are given the results of the analyses made up to the present. The degree of fluidity appears to bear a direct ratio to the percentage of petroleum spirit extract present, this constituent varying from 45.56 per cent. in a hard specimen to 56.48 per cent. in the soft Albany mineral. The total bituminous (asphaltic) matter ranged from 98.70 per cent. to 99.19 per cent.—a very short range. Non-bituminous organic matter was negligible in amount.

* See also L. K. Ward, Geol. Survey, South Austr., Bull. 2. The possibilities of the Discovery of Petroleum on Kangaroo Island and the Western Coast of Eyre's Peninsula.

TABLE I.

COMPOSITION OF FOREIGN ASPHALTUM AND RELATED SUBSTANCES.

	Asphalt, Pitch Lake, Trinidad.	Asphalt, Pitch Lake, Trinidad.	Maltha, Mexico.	Asphaltum Bermudez, Venezuela.	Gilsonite Cinta Co., Utah.	Tabbyite Tabby Cam., Utah.
Moisture	..	..	..	..	..	..
Soluble in Petroleum Spirit *	..	..	..	..	..	..
Bitumen insol. in Pet. Spt. †	41.00	13.7	87.12	18	.35	.91
Non-bituminous Organic matter	19.36	18.63	10.19	34.40	61.70	58.50
Earthy matter	3.94	10.85	2.40	56.54	37.94	36.13
	35.70	36.72	.29	3.74	none	.72
				5.32	.36	.65
	100.07	100.00	100.00	100.18	100.35	100.91
Sulphur	..	..	..	..	..	..
Spec. Gravity	4.22	6.16	1.48	4.70	.52 ‡	1.24
	1.372	..	..	1.05	1.018	1.006
	Asphaltum Hasbaya,? Syria.	Maltha Alcatraz, California.	Manjak Barbadoes.	Artificial Petroleum Pitch, California.	Coal-tar Pitch Source.?	Wood Pitch, Stockholm.
Moisture	..	..	..	..	..	..
Soluble in Petroleum Spirit *	..	..	..	..	..	..
Bitumen insol. in Pet. Spt. †	48.16	89.1	97.00	65.5	24.44	91.46
Non-bituminous Organic matter	51.16	10.4	.68	21.2	75.36	7.70
Earthy matter	traces	trace	2.32	13.7	.20	.84
	.68	.5		.6		
	100.00	100.00	100.00	100.00	100.00	100.00
Sulphur	..	..	..	..	..	..
Spec. Gravity	6.13	1.32	1.123	.74	.59	.01
	..	..		..	..	..

* "Malthene" of C. Richardson.

† "arbene" of C. Richardson.

‡ Often much higher.

TABLE II.
COMPOSITION OF ASPHALTUMS FROM THE SOUTH COAST OF AUSTRALIA.

		outh of Warren River.	Near Warren River.	Doubtful Island Bay.	Albany Harbour.	South Coast of W.A.	Ocean Beach near Esper- ance.	Kangaroo Island, S.A.
G.S. Museum No.	..	3,429	..	4,448	6,677	6,648	5,308	..
Moisture	..	.56	.58	.62	.73	.50	.06	.40
Soluble in Petroleum Spirit	..	49.47	49.44	47.00	56.48	45.56	43.94	47.57
Bitumen insoluble in Petroleum Spirit	..	49.37	49.33	51.88	42.22	53.74	55.38	51.62
Non-bituminous Organic matter	..	none	none	none	trace	trace	.52	.20
Earthy matter	..	.60	.65	.50	.57	.20	.10	.21
Sulphur	..	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Specific Gravity	..	..	..	..	1.039 to 1.044 *	3.32	3.70	..
Analyst	..	Simpson	Simpson	Simpson	Simpson	Simpson	Bowley	Bowley
Description	..	Hard ex- terior, softer centre.	Lake 3,429	Lake 3,429	Soft semi- fluid interior, somewhat harder ex- terior	Fairly hard and brittle	Lake 3,429	Lake 3,429.
	..	Solid throughout.						Analysis made of harder portion. 9,1.0507

* After exposure to the air in small fragments. Fresh fragments from the centre of the masses floated for sometime in brine, ranging between 1.025 and 1.032. This was in part, but not wholly, due to enclosed and attached air bubbles.

The earthy matter was always less than one per cent., varying from 0.20 to 0.65. It consisted almost wholly of clean sand grains from the beaches adhering to the surface or wedged into crevices. Moisture varied from 0.40 to 0.73 per cent.

Small gas bubbles occurred rarely in the heart of the masses and others often adhered persistently to the walls of crevices when the material was immersed in water. The effect of these in lowering the specific gravity of the whole mass must not be overlooked when dealing with the possibility of distribution of the mineral by the ocean.

In Table I. were given some analytical figures with regard to other asphaltums and related artificial substances, which should be compared with the Western Australian asphaltum. This latter is almost identical with the best Syrian asphaltum in composition, and closely related to the asphaltum from Bermudez in Venezuela, and to the so-called "Tabbyite" of Tabby Canyon, in Utah.

The specific gravity of the Australian mineral ranges from 1.025 to 1.050. It has a perfume resembling that of kerosene. It melts at varying temperatures below 100deg. C. and ignites readily, burning with a smoky flame.

SOURCE OF THE SOUTH COAST ASPHALTUM.

The asphaltum is at present distributed in small amounts along the coast line for a distance of at least 1,500 miles. This present distribution may be due to a widespread series of local sources, or to distribution from a limited number of sources by ocean currents. Finally, if the possibility of ocean distribution be conceded, the origin of the mineral may be either Australian or foreign.

With regard to the question of ocean distribution, it is to be noted that no asphaltum has been recorded from the south coast that has not been found in situations to which it could have been carried by ocean currents and tides, followed on occasion by a movement a few yards inland by gales of wind or more rarely by human agency. Thus most of it has been found on the ocean beaches near high water mark, a small amount has been dredged from the floor of a harbour, some has been obtained from tidal estuaries, some from sand dunes close to the ocean beach.

L. K. Ward has recently stated that * "the specific gravity of sea water is, in the Southern Ocean off the coast of South Australia, about 1.0285." The temperature at which this specific gravity was taken is not stated, but we may assume that the maximum density attained by the water of this ocean in the winter is 1.0290. From the nature of the specimens of asphaltum from the South Coast, which have been examined, it appears highly probable that prior to its exposure to the air it was all of the semi-fluid type, having a

* Loc. cit., p. 14.

specific gravity (when free from sand grains) not greater than 1.027, as indicated by experiments made with the Albany and Kangaroo Island material. The original specific gravity may well have been still less, the freshest fragments experimented with having had abundant opportunity of losing part of their lighter and more volatile constituents. The Government Analyst of South Australia* has noted specific gravities as low as 1.017 and 1.018. There is no doubt, therefore, of the capacity of the ocean to float and distribute this material, and the probability of its having done so is emphasised by the constant association with it of such sure ocean drift as angular fragments of pine resin, New South Wales kerosene shale, beeswax, etc. Ward gives a map† of the ocean currents round the coasts of Australia, from which it appears that a westerly current passes along the south coast of Australia from near the western end of Bass Straits to Cape Leeuwin. It seems reasonable to believe that the widespread occurrence of small quantities of asphaltum of one fixed type along just this stretch of coast is due not to innumerable local sources of supply, but to the distributing effect of this current on material derived from a limited number of sources.

The majority of natural asphalts find their way to the surface through porous beds of sand, clay, or limestone, and entangle in their mass considerable quantities of these earthy substances. Only those asphaltums which have collected in open fissures in firm rocks, *e.g.*, the "gilsonite" of Utah and the "manjak" of Barbadoes, are as free from earthy matters as the asphaltum of the southern Australian coasts. The latter has probably, therefore, been at one time a fissure filling.

The location of the original fissures is a problem of prime economic importance and one which has already engaged the attention of the field geologists of the Geological Survey. The fissures if local, are probably submarine, since long continued search along the coast has failed to reveal any such above sea level. It is, however, quite possible that the mineral is an importation to these shores, and that the relatively small quantity of it which has been discovered is derived from a jettisoned or wrecked cargo, or from supplies of material brought to Australian waters by American whalers for caulking their boats, and abandoned on beaches where whaling boats have been careened and caulked. At the same time, the occurrence on and near the South Coast of beds of brown coal and lignite (at Donnybrook, Fly Brook, Nornalup Inlet, Fitzgerald River, etc.) and of Tertiary volcanic rocks (at Bunbury, Black Point, Mount Silver, Donnelly River Mouth, Albany, etc.) indicates the possibility of the formation of petroleum and asphaltum during Tertiary and later times by the action of volcanic heat on buried coal seams and other sedimentary organic substances.

* Quoted by Ward, *ibid.*

† *Ibid.*, p. 25.

SUMMARY.—The South Coast asphaltum is a true petroleum residual. It occurs in small masses of identical type along 1,500 miles of coast line, and is confined to the immediate vicinity of the ocean. It is capable of having been floated by sea water, and whilst it may be derived from local sources, it is more probably the ocean drift from jettisoned or wrecked cargo, or from supplies brought by whalers for caulking their boats.

Perth, 25th September, 1914.

APPENDIX II.

PETROLOGICAL DESCRIPTIONS OF SOME ROCKS FROM THE WARREN RIVER DISTRICT.

By

R. A. FARQUHARSON, M.A. (Oxon), M.Sc., F.G.S.

[3452]: S. 252*.—Loc. A little north of Mount Silver—*Vesicular Basalt*.

In section, the rock consists of large columnar porphyritic crystals of basic plagioclase showing pronounced albite twinning and less numerous—in fact only occasional—platy phenocrysts of colourless augite in a fine-grained ground-mass of minute grains of augite and laths of felspar. Very common in the slide are small patches of yellowish-green almost isotropic and spherulitic chlorite, and in places are vesicles which are lined by thin layers of this mineral. Granular iron ore is fairly common, scattered in dusty aggregates all over the slide.

The rock is a fine-grained vesicular *porphyritic basalt*.

[3453]: S. 253*.—Loc. Black Point—*Columnar Basalt*.

This rock is essentially the same as [3452] but the small patches of green chlorite have no spherulitic or radial structure, and there does not appear to be a vesicular structure as in the former. The rock differs from [13715] in its finer grain and more pronounced basaltic structure.

[13708]: S. 2314.—Loc. Black Head—*Quartz-hornblende Rock*.

A dense, black, fine-grained rock with indistinct cracks, closely resembling a doleritic basalt, but with a reddish, almost imperceptible, tinge in places.

* Collected by A. Gibb Maitland, Government Geologist.

In section, the rock is found to consist of grains of quartz, grains and ragged plates of green hornblende that are partially or wholly altered to chlorite and that occur sparingly, and in places yellowish grains of epidote and much pinkish garnet in grains and granular aggregates. Felspar, though possibly present, was not identified in the slide. The quartz plates show slight irregular extinction suggestive of straining in the rock. The structure is essentially granular.

The rock is a black *garnetiferous quartz-hornblende rock*, perhaps a facies of a massive fine-grained garnetiferous quartz-amphibolite, though a faint suggestion of banding in the specimen indicates an approach to gneissic structure.

[13709]: S. 2459.—Loc. Black Head—*Gneiss*.

A coarse-grained, dark-grey rock with somewhat jointed structure and a gneissic banding. In section, it proves to be a *pyroxene-gneiss* with some patches of brownish biotite. The colourless constituents, both quartz and felspar, have been severely crushed, exhibiting numerous cracks, pronounced irregular and undulatory extinction, rows of pores and partial granulitisation. There is also somewhat parallel arrangement or elongation of the crushed plates.

[13710]: S. 2312.—Loc. Callep Ford, Warren River—*Dolerite*.

A medium-grained almost black rock with a brown-red crust. In section, the rock consists largely of irregular plates of brownish augite in ophitic relationship with numerous long acicular crystals of twinned basic felspar frequently forming a plexus, and frequent small colourless grains of a mineral which, owing to its very high birefringence, high refractive index, absence of cleavage, and, in places, its alteration to a fibrous yellowish-green product, has been referred with doubt to olivine.* There are also a few small forms of a brown pleochroic hornblende, and a considerable amount of black iron ore.

The rock is a fine-grained *ophitic dolerite*.

[13711]: Loc. Oil Leases, Warren River—*Ferruginous Sandstone*.

A fine-grained dark brownish-red granular rock. In section, it consists of sub-angular and rounded grains of clear quartz cemented by a red ferruginous cement. In rare cases, some minute colourless needles are visible in some of the quartz grains.

The rock is a ferruginous sedimentary *sandstone*.

[13713]: Loc. Oil Leases, Warren River—*Amphibolite*.

A somewhat weathered finely foliated amphibolitic rock of medium grain with a faint pink tinge in the green on the fresh surface. There is a yellow limonitic crust.

In section, the rock consists of irregular green hornblende plates separated largely by clear platy quartz and felspar, and with

* Thorough optical examination was impossible under the circumstances.

numerous rounded crystals of pink garnet, to which the pink tinge is due. The grain is rather coarse.

The rock is a finely foliated *garnet amphibolite*.

[13714]: S. 2285, 2295, 2309, and 2340.—Loc. Scott's, Donnelly River—*Quartz Porphyry*.

A dark grey porphyritic rock with large crystals of felspar and smaller crystals of quartz and a pronounced shear or finely-foliated structure which causes some of the felspars to appear as thin lenticular "äugen."

The rock consists of large crystals of felspar and smaller crystals of clear quartz in a fine-grained platy holocrystalline ground-mass of quartz and felspar plates. In certain portions of the slide are numerous strings of fine scales of a yellowish to brownish green chloritised biotite arranged in much curved lines.

The larger felspars and quartz plates stand out clearly as "äugen," the biotitic strings sweeping round them in curved lines and often completely enveloping them. Immediately round some of the larger felspars, and appearing as a rim or border are granulitised clear plates of quartz and felspar, due doubtless to the breaking down of the margins of the phenocryst; and the margins of some of the quartz phenocrysts are also much granulated. Cracks are seen in both the felspar and the quartz. Irregular extinction is common to both, and the former, which in the sections examined is without any albite or pericline lamellation and is in general untwinned, appears to have had in some instances a secondary and irregular lamellation induced in it. This in rare cases simulates an incipient microcline structure, or may actually be it. All the larger plates are more or less elongated parallel. The micaceous strings occur in bands, the intervals being occupied by clear mosaical plates of quartz and felspar. Augen structure is clear in the smaller lenticles of felspar and quartz in the biotitic bands. A grain or two of an isotropic mineral referred to garnet was observed.

The rock is an intensely foliated weathered *quartzose porphyry*.

[13715]: S. 2443.—Loc. Black Point—*Columnar Basalt*.

A medium-grained fresh black rock with numerous reflecting surfaces of felspar. The section consists almost wholly of long and short columnar felspars with platy and granular colourless augite in ophitic relation with them. There are some dark chloritic patches and some granular iron ore. In places, a second more minute series of felspar laths is observable.

The rock is a fresh *ophitic dolerite*.

[13716]: S. 2444.—Loc. Black Point—*Calcite*.

A peculiar fine-grained rock, in places soft and brownish in colour, but in others harder and black owing to metallic staining. It effervesces (especially in the brownish portions)) strongly with cold dilute hydrochloric acid.

In section, the rock consists almost wholly of fine granular calcite, which is, in places, seen to be stained by a brownish black staining (probably hydrated ferric oxide). A little greenish isotropic chlorite appears in places. The origin of the rock is doubtful. It may be a decomposition product of a fine-grained dolerite, but no relics of structure are visible.

It is now a fine-grained granular *carbonate (calcite) rock* with some small chlorite patches.

[13717]: S. 2212.—Loc. Darradup, Blackwood River—*Porphyritic Basalt*.

A clayey, yellowish-grey weathered rock with large yellowish more or less porphyritic feldspars.

In section, the main mass is made up of numerous small columnar or lath-shaped twinned feldspars, in the interstices of which are small and large grains of colourless augite. In places the feldspars reach considerable size and occasionally appear as exceptionally large, broadly lamellated phenocrystal forms in the finer ground-mass. The species is, in all cases observed, basic, about labradorite. The structure is typically finely ophitic.

The rock is a weathered fine-grained *porphyritic dolerite*.

[13717]: S. 2492.—Loc. Darradup, Blackwood River—*Porphyritic Basalt*.

A fresh coarse-grained slightly vesicular black rock with large yellowish feldspar crystals.

In section, the rock consists in general of large and small columnar crystals of a fresh strongly twinned basic plagioclase—basic labradorite—with a considerable amount of greyish augite in shapeless crystals or large grains and in very distinct sub-ophitic relationship with the feldspar. In places, however, are black areas containing much iron in which are numerous microlites of feldspar and apparently needles of greyish brown augite. Occasional almost isotropic green chloritic patches occur which very doubtfully represent former olivine, but more probably altered augite. Some of the feldspars are of distinctly porphyritic habit, though always in columnar form; a few exhibit zonal structure and most are twinned strongly on the albite law.

The rock is a *porphyritic dolerite basalt*, and it appears to be a transition facies between an extrusive dolerite and a basalt, having in part solidified as a basalt and in part as a coarse-grained dolerite.



1914

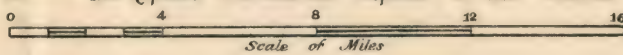


Hon P. Collier M.L.A.
MINISTER FOR MINES

GEOLOGICAL SKETCH MAP OF THE EXTREME SOUTH WESTERN PORTION OF WESTERN AUSTRALIA

BY
H. P. Woodward Assistant Government Geologist

To accompany Report on — The Reputed 'Petroliferous' Deposits of the 'Warren' River District.



BULLETIN No 65. PLATE II.



Alfred H. Woodward
GOVERNMENT GEOLOGIST.

R.H. Irwin del.

EXPLANATION

- | | | | |
|------------------|----------------------------|--|---|
| SAND DRIFTS..... | CALCAREOUS SANDSTONES..... | GNEISSIC GRANITE DARLING RANGE SERIES..... | PORPHYRITIC GRANITES ALBANY SERIES..... |
| | | | |
| | T | G | Gn |
| | | FEET ABOVE SEA LEVEL..... | |
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TOPOGRAPHY BASED ON LANDS & SURVEYS DEPT. MAP 1.

H. J. Pether, Government Lithographer, Perth, W.A.



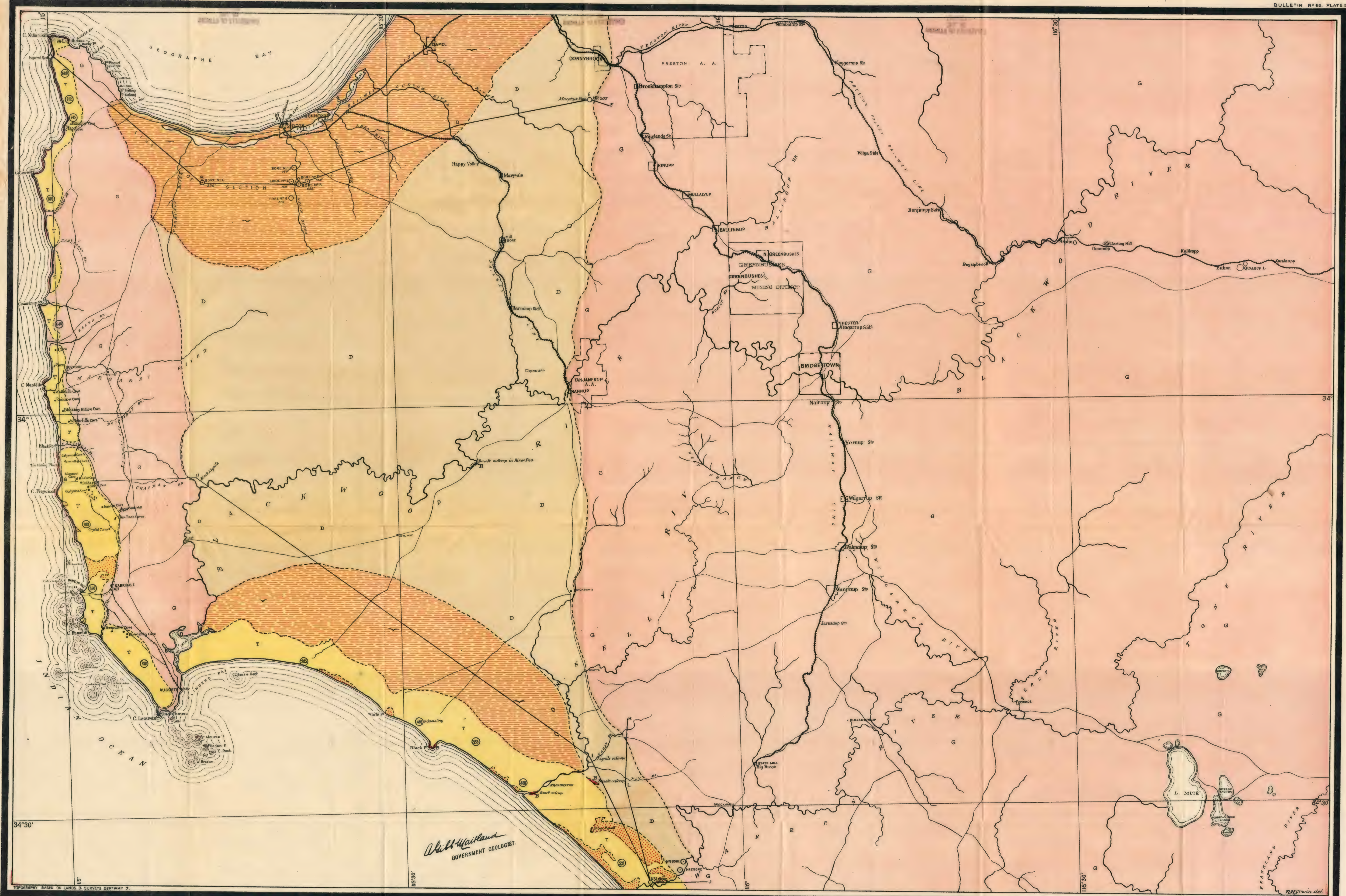
Hon P. Collier M.L.A.
MINISTER FOR MINES

GEOLOGICAL SKETCH MAP THE EXTREME SOUTH WESTERN PORTION OF WESTERN AUSTRALIA

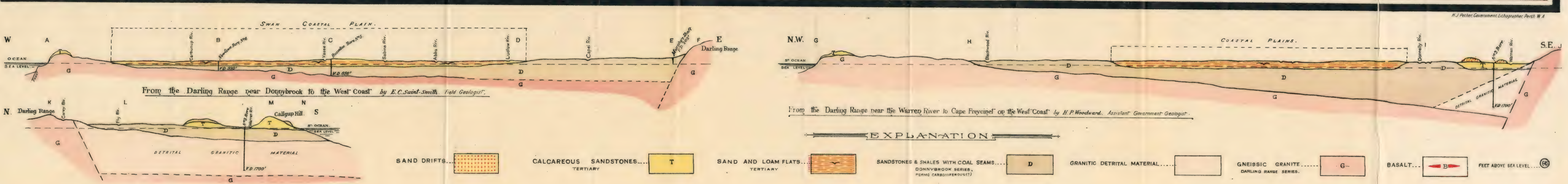
BY H. P. Woodward Assistant Government Geologist & E. C. Saint-Smith Field Geologist
To accompany Report on — The Reputed "Petrofiferous" Deposits of the "Warren River District."

Scale of Miles
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BULLETIN No. 65. PLATE I.



Albert W. H. Woodward
GOVERNMENT GEOLOGIST.



From the Darling Range to South Coast at Meerup Brook by H. P. Woodward, Assistant Government Geologist.

INDEX.

	Page.
Albany Harbour	15, 48
Albertite	42
Artesian Oil Wells Co.	15
Asphalt	42, 45
Asphaltene	43
Asphaltic Oils	41
Asphaltum	8, 12-14, 20-24, 37, 40, 42, 45, 47
Augusta	11, 18
Barlee Brook	10
Bitumen (<i>see</i> Asphaltum)	
Bituminous Clay	20, 26, 27
Black Head	11, 49, 50
Black Point	9, 10, 18, 19, 48, 49, 51
Blackwood River	18, 22
Brockman, W. L.	11, 22
Brown, H. Y. L.	21, 22
Bunbury	48
Callcup Ford, ...	50
Carbene	43, 45
Carne, J. E.	12, 14, 31, 32
Clarke, Rev. W. B.	12
Coal Deposits	20, 27, 38
Coastal Plains	17, 18
Coorongite	40
Craig, E. H. Cunningham	20, 30, 38, 41
Darradup	18, 52
Donnelly River	9, 11, 18, 19, 29, 48, 51
Donnybrook	48
Dougall, S. S.	13, 24-26, 28
Dunes	17, 19
Dung-bitumen	40
Elaterite	40
Eldridge, G. H.	40
Endemann's Distillation Method	43
Eyre's Peninsula, S.A.	22
Farquharson, R. A.	8
Fitzgerald River	48
Flinders Bay	18
Fly Brook	17, 20, 27, 38, 48
Fly Brook Series	18, 19, 28, 37
Foot-hills	17, 18
Fossils	30
Gilsonite	42, 45, 48
Glance Pitch	42
Glenelg River, S.A.	22
Göczel, S.	9, 11, 16, 23, 25, 26, 29-31, 33, 38
Grahamite	42

	Page
Hardman, E. T.	21
Kangaroo Island, S.A.	22, 46
Linton's Extraction Method	43
Maitland, A. Gibb	9, 13, 15, 18, 21, 31
Malamup	12, 22
Maltha	42, 45
Maltlene	43, 45
Manjak	42, 45, 48
Meerup Brook	10, 11, 22, 29
Meudell, Geo. D.	15, 16
Montgomery, A.	11, 12, 16, 21, 25, 29
Mt. Silver	18, 48, 49
Murray River	22
Nankivell, E. J.	8, 11, 14
Nornalup Inlet	48
Oil-like Scum	20, 24, 25, 37
Paraffin Oils	41
Permo-Carboniferous Rocks	18
Petrolene	43
Physiographical Geology	17
Pitch	42
Port Lincoln, S.A.	22
Princess Royal Harbour Mineral and Oil Co.	15
Redwood and Holloway	40
Regulations controlling Prospecting for Oil	8
Saint-Smith, E. C.	8
Scott River	18
Scum, Oil-like	20, 24, 25, 37
Simpson, E. S.	8, 14, 24, 26
Sinclair & Boyd	8, 13
Tabbyite	42, 45, 47
Tate, Ralph	22
Thompson, A. Beeby	41
Torbanite	40
Wade, Dr. A.	7
Wallcott, P.	13
Ward, L. Keith	22, 47
Warren River	11, 18, 29
Warren River Bores	12, 18
Western Australian Mining Syndicate	8
Westralian Mining & Oil Corporation, Ltd.	8, 9, 11, 13, 16, 28, 32
Yorke Peninsula, S.A.	22

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WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

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BULLETIN No. 66.

FEB 22 1916

THE GEOLOGY OF THE COUNTRY

TO THE

SOUTH OF KALGOORLIE

(COOLGARDIE AND EAST COOLGARDIE GOLDFIELDS),

INCLUDING

The Mining Centres

OF

Golden Ridge and Feysville,

BY

C. SIDNEY HONMAN, B.M.E. (MELB.),

FIELD GEOLOGIST.

*Issued under the Authority of the Hon. P. Collier, M.L.A.,
Minister for Mines.*

WITH NINE PLATES AND SEVENTEEN FIGURES.



PERTH:

BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.

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1916.

W 52 Geol.
V. 66 N. H. L.

PREFATORY NOTE.

This Bulletin gives the results of an examination of about 700 square miles of country in portions of the Coolgardie and East Coolgardie Goldfields, lying to the south of Kalgoorlie, and co-terminous with that described in Bulletin 56, *q.v.*

The report is based upon field work carried out by Mr. Honman during the period intervening between the months of April, 1913, and January, 1914, with but a brief interruption during September and October.

The country embraced by Mr. Honman's survey, the results of which are published on the scale of one and a-half miles per inch, falls within portions of the 40-chains lithographs L9 and L10 issued by the Department of Mines, and Sheet 25 of the 300-chains series of the Department of Lands and Surveys.



GOVERNMENT GEOLOGIST.

Geological Survey Office,
Perth, 23rd June, 1916.

TABLE OF CONTENTS.

	PAGE
PREFATORY NOTE	3
INTRODUCTION	9
TOPOGRAPHY—	10
The Higher Land	10
The Sand Plains	11
The Dry Lake Country	11
GENERAL GEOLOGY—	12
Succession	12
DESCRIPTIVE GEOLOGY—	14
Kalgoorlie Series	14
Greenstones (Volcanic)	14
The Golden Ridge Belt	14
The Feysville Belt	15
The Somerville-Woolabar Belt	15
The Mt. Marion-Yilmia Trig. Belt	16
Volcanic Agglomerates	17
Porphyrite (Volcanic)	18
Agglomerates	21
Sedimentary Rocks	21
Intrusives	24
Peridotite and derivatives	24
Amphibolised Dolerite and Gabbro	25
Quartz Porphyry and Porphyrite	26
Granite	32
Newer Gabbro (Norite)	34
The Kurrawang Series	35
Recent (Superficial)	35
Alluvium	35
Dry Lake Deposits	36
Aeolian Plains	36
Travertine	36
Laterite	37
STRUCTURAL GEOLOGY—	38
Folding	38
Foliation or Cleavage	38
Shearing	39
Planes of Parting	39
Faulting	39
Strike Faults	39
Dip Faults	40
Conclusions	42
MINING GEOLOGY	43
Golden Ridge	43
History	43
Topography	44
Geology	45
Economic Geology	49
Description of Reefs	51
Mineralisation of the Reefs	52
Ore Genesis	53
Future Prospects and Recommendations	55
Boorara	56

TABLE OF CONTENTS— <i>continued.</i>		PAGE
Feysville		60
The Speakman Syndicate		60
Little Wonder G.M.L. 17		63
Battery Lease No. 1, Location 50		64
Battery Lease No. 3, Location 50		64
The Michael Angelo Lode G.M.L. 3746E		65
G.M.L. 2717E (abandoned)		66
G.M.L. 1242E (abandoned)		66
The Country West of Lake Lefroy		68
Conclusion		70
INDEX		71

LIST OF PLATES.

I.—Geological Map and Section of part of Coolgardie and East Coolgardie Goldfields, South of Eastern Goldfields Railway ..	} At end
II.—Do. do. do. do. ..	
III.—Geological Map of Golden Ridge	
IV.—Geological Map of Upper Workings of the Golden Ridge Gold Mine	
V.—Geological Map of Lower Workings of the Golden Ridge Gold Mine	
VI.—Geological Sections of Golden Ridge Gold Mine	
VII.—Longitudinal Sections of Workings of Golden Ridge Gold Mine ..	
VIII.—Sections of Various Geological Features on Golden Ridge Gold Mine	
IX.—Geological Map of Speakman Syndicate Properties	

LIST OF FIGURES.

	PAGE
1. Plan of outcrop of porphyrite and sedimentary beds east of Feysville	20
2. Plan of outcrop of sedimentary beds south-east of Feysville ..	21
3. Photograph of hand specimen [13643] from near 8-mile post on Bulong Road	23
4. Section across western shore of Lake Country	36
5. Photograph of hand specimen [13651] of alluvial cement at 6½ mile post on Bulong Road	37
6. Diagrammatic section of the Kurrawang Fault	41
7. Diagram showing fracture in Golden Ridge porphyry	48
8. Compression tests on sandstone	50
9. Fissures formed along a fault plane	51
10. Photograph of specimen [13569] from Golden Ridge No. 2 Cross Reef, 465-ft. level	52
11. Sketch plan of No. 2 Level of old Boorara workings, Golden Ridge G.M. Co.	57
12. Plan and sections of Higgins & Party's workings at Boorara ..	59a
13. Shear and parting planes in porphyry on Speakman's workings, Location 50	62
14. Cross-section of Little Wonder Lease, Location 50	64
15. Plan and Cross-section of Hassell's Mine (Michael Angelo Lode) at Feysville	64a
16. Section of Reefs on G.M.L. 1242E, Feysville	66
17. Section of Reefs on G.M.L. 2708E, Feysville	67

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA.

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THE GEOLOGY OF THE COUNTRY TO THE SOUTH OF KALGOORLIE, INCLUDING THE MINING CENTRES OF GOLDEN RIDGE AND FEYSVILLE.

I.—INTRODUCTION.

The area described in this report embraces the mining centres of Golden Ridge, Boorara, Feysville, Location 50 of the Hampton Properties, Ltd., and a tract of country lying west of Lake Lefroy reaching to within 10 miles of Widgiemooltha. It was intended to include Location 48 and the Red Hill Centre, but owing to an interruption in September and October the mapping of these centres had to be left to a future date.

The field work was commenced in April, 1913, and, with the break in September and October already referred to, was continued till January, 1914.

This report does not pretend to be descriptive of an exhaustive geological survey of the area covered, because except for the Golden Ridge Mining Centre, the whole area has only been mapped in a more or less broad way. The chief object of the work was to delineate the most important structural features so that they might serve as a basis for future detailed mapping, should such be deemed necessary at any time.

The Golden Ridge Mine has been mapped as far as possible in detail and a preliminary report on the same has already been published in Bulletin No. 59, pp. 176, *et seq.*

The total area traversed is between 600 and 700 square miles, and is continuous with the belt of country mapped between Kalgoorlie and Coolgardie, which has been described in Bulletin No. 56.

I am indebted to the mine managers and prospectors of the district for their cordial co-operation in carrying out the field work, and to Mr. G. R. Dugdale for his valuable and ready services as Field Assistant.

Nearly a hundred of the specimens collected in the course of the field work were examined by the Petrologist, Mr. Farquharson, and his determinations have been availed of in the compilation of the petrography of the district.

The accompanying geological map has been issued in two parts:

Plate I.—The northern portion of the district which, for purposes of correlation, includes the outline of Mr. C. G. Gibson's work at Kalgoorlie and Boulder (*vide* Bulletin No. 42), and of the work carried out by myself in the country between Kalgoorlie and Coolgardie (*vide* Bulletin No. 56).

Plate II.—The southern portion of the district showing the geology of the country west of Lake Lefroy and geological cross-sections. Plate II. is the southern continuation of Plate I.

Included in the report are also larger scale maps of the Golden Ridge and Hampton Boulder (Speakman's Syndicate) Centres, with various underground plans and sections.

II.—TOPOGRAPHY.

The area is not characterised by any marked relief, and the landscape of the surrounding country presents to the observer a more or less monotonous and flat appearance, broken very occasionally by a group or range of hills.

The physiographical features may be divided into three classes—

1. The Higher Land.
2. The Sand Plains.
3. The Dry Lake Country.

THE HIGHER LAND comprises the more prominent physical features of the district and includes all the hills, ranges, and granite plateaux. The average height of the tops of the hills is about 1,400 feet above sea level. The higher land represents the remnants of a pre-existing land surface since worn away by disintegration, erosion, and wind action. Owing to the changes in the climate caused by the gradual elimination of high mountain ranges which must have previously existed, the disintegrating and wind-acting factors now predominate over erosion, resulting in the filling up of the valleys with disintegrated rock and wind-blown detritus. The erosive action is insufficient to remove the enormous accumulations of detrital material in the valleys, and consequently, after thunderstorms, the large quantities that collect with but little potential energy soak the wide plains, thus forming strings of salt lakes in the depressed areas.

The higher land has geologically a more or less structural significance in that the form of the ranges and hills conforms with the distribution of the rocks of the district. The higher land may be divided into three types according to the geological structure and constitution of the composing rocks.

1.—Elongated ranges and ridges representing the upturned edges of long belts of older greenstones. The following ranges come under this heading:—

- (a) the range of hills running through Boorara;
- (b) Mt. Shea and neighbouring hills;
- (c) the range of hills trending irregularly from the Kalgoorlie abattoirs S.S.E. through the N.E. corner of Location 53, a few miles east of Wongi;
- (d) parts of the irregular range through Location 50;
- (e) Yilmia Trigonometrical Station and the adjoining hills.

2.—Short ridges representing the outcrops of newer greenstones of which Mt. Goddard and a short range running westerly from Woolabar are examples.

3.—Flat-topped rises of granite country. These are represented by the granite tableland the highest point of which occurs at the Horse Rocks from where there is a gradual fall southwards towards Widgiemooltha.

The lower portions or valleys of the higher land are occupied by wide alluvial flats formed apparently by water action in times of heavy rainfall. Very often the flats are devoid of any creeks, though usually a dry and ill-defined water-course is found meandering along them parallel with the neighbouring ridges, and occasionally supplied with crude tributaries from the more prominent hills. In the hills themselves, gullies and creeks radiate into the flats where they very soon become obliterated.

THE SAND PLAINS cover many miles of country and are generally the result of wind action on the higher land and the lake surfaces. The products of disintegration on the higher land, and the dust and salts of the lake are blown across the latter from the north-west. These become spread over the country south-east of the lakes, forming a sand plain which gradually rises towards the higher land. The higher land, in some instances, is partially buried on its north-west flank by the encroaching sand from the next string of lakes to the north. These plains are devoid of outcrop and hide from view many miles of the geological structure of the country. The sand plains extend south-east of the Kurrawang lakes to the foothills of Mt. Shea and also south-east of Hannan's Lake to Boorara, Duplex and Simplex hills, and close to the shores of Lake Lefroy.

THE DRY LAKE COUNTRY is represented by Hannan's Lake, the northernmost limit of which is at Lakeside, and which widens southwards towards Feysville, giving it a somewhat pear-shaped appearance on the map. From near Feysville an arm extends southwards, bounded on the east by sand plain and on the west by the Mt. Shea group of hills. This arm continues southwards through Slate Well as a series of alternating strings of lakes and samphire flats until it joins Lake Lefroy near Red Hill. Hannan's Lake probably owes its greater width at its southern end to the boss of felspar-porphry north of Mt. Shea. This boss of hard intrusive rock would act as a dam to the southern end of the valley between the Kalgoorlie and Golden Ridge greenstone belts, thus causing the waters of Hannan's Lake to spread out, forming the wide surface covered by the now dry lake. There is a continuous depression which extends from between Kalgoorlie and Golden Ridge passing east of Feysville and through Slate Well. This probably represents a band of soft sedimentary rocks which have been recognised east of Kalgoorlie by Gibson, and can be seen abundantly outcropping in the neighbourhood of Slate Well. Sedimentary rocks are also represented near the eastern foot of the Mt. Shea group of hills.

The general topography and vegetation is similar to that of the country to the north-west described more fully in Bulletin No. 56.

At Lakeside Railway Station, Hannan's Lake is 1,000 feet above sea level. Lake Lefroy at Widgiemooltha is about 900 feet, showing that the lake country has a general fall to the southwards.

III.—GENERAL GEOLOGY.

SUCCESSION.—Since the publication of Bulletin No. 56 on the geology between Kalgoorlie and Coolgardie, considerable light has been thrown on the problems of the district by the work embraced by this report, and a geological survey of the Mt. Jackson district which was made last year in conjunction with a general survey of the North Yilgarn Goldfield.

This later work in both areas has demonstrated without any doubt the existence of an unconformity between the ancient greenstone schists and the Kurrawang sedimentary series. At Mt. Jackson a series of conglomerates occurs bearing a strong resemblance to the Kurrawang series, though they are not sheared to the same extent. At Kurrawang the unconformity is not so evident as both series have the same strike, but as pointed out in Bulletin No. 56, there is a decided difference in texture between the Kurrawang rocks and the neighbouring series, as emphasised in that report by classing the former as gneissic sediments and the latter as porphyritic schists. Taking the later evidence in conjunction with the occurrence of pebbles in the conglomerates formed from the rocks of the older series, there is no doubt that the Kurrawang series is an unconformable younger series resting on the ancient greenstone schists and porphyritic schists.

Mr. Gibson, in his account of the geology of Kalgoorlie, has already pointed out the younger age of the Kurrawang conglomerates.

The Kurrawang conglomerates contain bands of porphyry conglomerate and slaty conglomerate the pebbles of which were derived from the porphyries and slates occurring in ancient greenstone series. The thickest and most prominent bands of conglomerate are composed largely of pebbles of hematite-quartzite and banded quartzites, which are poorly represented in the district. These must, therefore, have come from a considerable distance; probably from the continuation of the Mt. Jackson Range, 100 miles north-north-west, or, as pointed out by Mr. Gibson, from the Edjudina series some 80 or 90 miles east-north-east of Kalgoorlie. As the Mt. Jackson Range strikes for Kalgoorlie, it is most probable that the nearest point of the Mt. Jackson belt is much less than 100 miles from Kalgoorlie.

Generally, therefore, the geology of the district may be described as consisting of three distinct series: an ancient series of greenstone schists, amphibolites and porphyrites; a later ancient

series of conglomerates, arkoses and slates; and a recent series of superficial deposits.

Excepting the superficial deposits all the rocks have been greatly metamorphosed by the pressures to which they must have been subjected by the great earth movements that have undoubtedly taken place in the Eastern Goldfields.

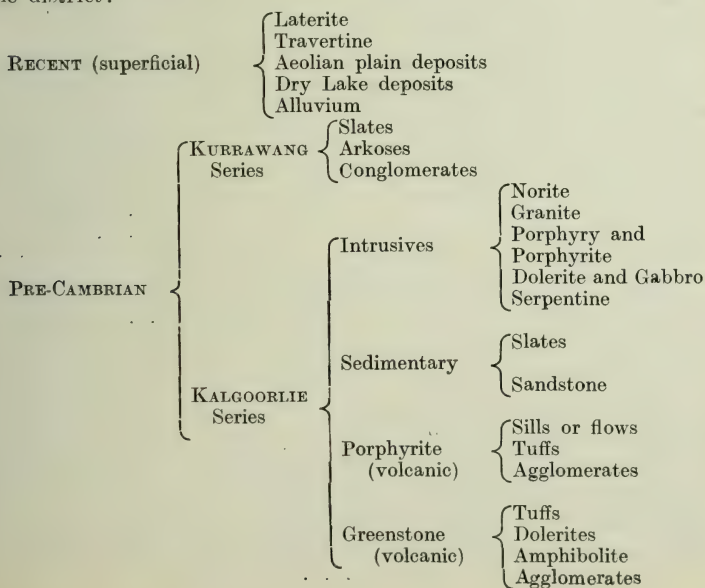
The rocks, which were originally laid down on an ancient complex, now represented by granite, in their primitive state consisted of a series of acid and basic lava flows, tuffs, breccias, and agglomerates. Following their formation there was a cessation of volcanic conditions. Terrestrial dissection took place with the accompanying deposition of beds of arkoses, slates, and conglomerates forming an unconformable series on the volcanic beds.

There then followed great folding and squeezing movements caused probably by shrinkage of the earth's crust. The folding and tilting was accompanied by regional metamorphism and shearing, giving the beds their present steeply inclined and schistose appearance in the field. Both series have been metamorphosed, though the younger series is not as contorted as the older series.

Subsequent intrusion by later intrusive dykes and bosses has still further increased the metamorphic effect, probably superimposing thermal on the dynamic effects.

Finally, long ages of denudation have reduced the surface to its present level, and recent deposits have been laid down in the form of lake deposits and sand plains.

The following is a tabulation of the succession of the rocks of the district:—



IV.—DESCRIPTIVE GEOLOGY.

The rocks are described in the above table in ascending order, starting with the older greenstones.

KALGOORLIE SERIES.

GREENSTONES (VOLCANIC).—These rocks are represented by the fine-grained greenstones and greenstone schists. They are petrologically classed as dolerites, amphibolites, and amphibolite schists.

The greenstones are represented by four main belts in the area under examination:—

- (1.) The Golden Ridge Belt;
- (2.) The Feysville Belt;
- (3.) The Somerville-Woolabar Belt;
- (4.) The Mt. Marion-Yilmia Trig. Belt.

Owing to great regional metamorphism the rocks of these belts of greenstone show great variations. The predominating type is amphibolite.

(1.) *The Golden Ridge Belt.*—A very altered greenstone series passes through Golden Ridge. The rocks are very highly carbonated and correspond with the calc schists of Kalgoorlie. Great difficulty was experienced in collecting absolutely fresh specimens.

The belt is two miles wide on the Bulong road extending from the six to the eight-mile posts; at Boorara its width is three miles. These rocks are associated with sediments, are very altered and sheared, and a great majority are schistose.

Under the microscope, according to Mr. Farquharson, they are seen to consist of red oxide-stained fine granular calcite, much altered forms that resemble original hornblende, and a form or two that may represent felspar. In most cases the extent of decomposition and metamorphism has hidden original structure. The petrologist is of the opinion that they are derived from amphibolites. In hand specimens they bear a great resemblance to the calc-schists of Kalgoorlie.

Some of the more schistose forms are talcose and chloritic and contain a considerable amount of calcite. The eastern country of the Golden Ridge Mine is a typical talc-chlorite-schist.

Some types are mottled, due to the presence of crystals of ferrous carbonate, and such occur between the Boorara ridge and the Boorara pumping station.

These rocks, which are therefore correlated with the calc-schists of Kalgoorlie, have probably been derived from amphibolites by carbonation and originally from lava flows and tuffs by regional metamorphism. The foliation and schistose structure have been pro-

duced by great lateral pressure resulting from the intrusion of massive volcanic rocks. The talc-schists probably represent zones of shearing.

In the Golden Ridge belt minor occurrences of sediments are met with, some of which are now represented on the surface by bands of ferruginous quartzite.

On the western margin of the belt the greenstones are more massive and have been described by the petrologist as amphibolised quartz-dolerite. This latter rock probably represents an intrusion in the greenstone series, or an altered phase of an original volcanic rock.

The presence of bands of agglomerates in the greenstones points with additional weight to their probable volcanic origin. These agglomerates represent beds of débris so commonly associated with volcanic rocks.

(2.) *The Feysville Belt.*—This belt extends from the south-west shore of Hannan's Lake to Feysville, and probably is an extension through Hannan's Lake of the western belt of Kalgoorlie greenstone.

It is bounded on the east and west by porphyrite and gives considerable physiographical relief to the locality in the form of the Mt. Shea group of hills.

This belt consists of fine-grained altered amphibolite and is largely carbonated, and where intersected by porphyry dykes is felspathised. There are three varieties represented:—

- i. A fine-grained bluish green rock, which under the microscope is seen to consist of small fibrous wisps of hornblende and kaolinised remains of felspar, and is classed as a fine-grained amphibolite or amphibolised dolerite.
- ii. A carbonated and chloritised amphibolite.
- iii. An altered felspar-chlorite-calcite rock probably derived from an amphibolite by felspathisation due to an intrusive dyke.

There are therefore three phases of alteration. Firstly, the formation of an amphibolite from a volcanic rock by regional metamorphism; secondly, local alteration to a carbonate rock due to altered conditions of temperature and circulation of solutions in the amphibolite; and finally, contact alteration and felspathisation in proximity to intrusive dykes.

(3.) *The Somerville-Woolabar Belt.*—On the Kalgoorlie-Coolgardie road at Somerville, Mr. Gibson has mapped this belt as two miles wide. Proceeding southwards along the belt, the width gradually increases and west of Mt. Hunt it attains a width of three miles, while east of Feysville, still further south, it reaches as much

as four miles. Abreast of Mt. Goddard the belt extends from east of Location 50 to the eastern boundary of Location 53, a distance of six miles across.

The greenstones of this belt are similar to the above belts but are less carbonated and less subjected to atmospheric decomposition, which is probably due to their less carbonated character. For the most part the greenstones are amphibolites, being derived from either a dolerite or basalt, probably the latter, as the field evidence and structural relations of the majority of the greenstones point to their volcanic origin. The presence of breccias and agglomerates, the variations across the strike of the belt, and an interbedding with banded quartzites and slaty rocks point clearly to such an origin. There is no doubt, however, that some of the amphibolites are derived from dolerites representing necks, sills, or dykes in the ancient lava beds. Good examples of such amphibolised dolerite and gabbro intrusives occur in Location 50 and at Woolabar.

The carbonated varieties—calcite, chlorite, and talc-schists—are confined to the neighbourhood of later intrusives of porphyry and granite; for instance, on the old Hampton Boulder Mine, Location 50.

According to the petrologist, typical specimens under the microscope are seen to be composed of plates, needles, and acicular aggregates of greenish hornblende. Plates and columnar crystals appearing almost as phenocrysts of feldspar in one case in a finely mosaical ground-mass that appears to have been derived from larger feldspars by granulitisation. Some of the hornblende plates have a border of deeper tone. The large feldspars and the mosaic ground enclose minute needles of hornblende. Lamellation appears in the feldspar and irregular extinction due to strain. The hornblende appears to have been derived from augite. Some quartz grains are observed which may be secondary. In some cases the rock is composed almost exclusively of small lath-shaped hornblende crystals.

Such rocks might easily be derived from a basaltic or allied volcanic rock by metamorphism.

(4.) *The Mt. Marion-Yilmia Trig. Belt.*—This appears to connect with the Somerville-Woolabar belt north of the Horse Rocks-Red Hill Road. The fine-grained amphibolites are associated with agglomerates and breccias which points to their volcanic origin. There are no signs of carbonation in this belt, as far as my own observations were carried, but there is the usual association with sedimentary beds.

Besides the above four beds of greenstone there are two others to the south-west. One extending from the 25-mile post on the Widgiemooltha road and following the road southwards; another cutting the Widgiemooltha telegraph line at the 35-mile post with the usual north-north-west strike. The former is probably the con-

tinuation of the Widgiemooltha auriferous country. No attempt has been made to differentiate the greenstones into fine-grained altered volcanics, and doleritic intrusives, except in Location 50 and at Woolabar where some large intrusive masses of hornblende dolerite have been mapped.

Volcanic Agglomerates.—In the fine-grained greenstone belts agglomerates and breccias are of frequent occurrence. Owing to their persistent strike, great width in places (up to 3 chains), and above all their undoubted fragmental appearance and lithological resemblance to cataclastic rocks, they are classed as volcanic agglomerates.

As regards the possibility of their derivation by crushing of the rock along lines of shearing, such explanation is untenable owing to their resemblance to agglomerates occurring in the porphyrite area interbedded with bands of slates and grits. Also the inclusion amongst the fragments of material foreign to the bulk of the fragments and the matrix. The fragments are all angular and when unweathered can be seen to be surrounded by a porphyrite matrix which may have originated from a tuff. The best occurrences of agglomerate are:—

- (a) North-west of Mt. Herbert;
- (b) Two miles east of the 58-mile post on the western boundary of the East Coolgardie Goldfield; and
- (c) One and a half miles west of Boorara on the Boorara pipe track.

The following is a description by the Petrologist of the last-named occurrence at Boorara:—

[13653] Breccia $1\frac{1}{2}$ miles west of Boorara.

“A brick-red rock with brecciated appearance, due to the presence in the red matrix of many small and large angular fragments apparently of a different rock. These fragments are best seen on the weathered surface. The reddish material effervesces with cold acid. A section shows a reddish granular mass enclosing patches, almost colourless, consisting of long kaolinised felspar columns and some platy quartz. In places some patches consist mostly of quartz, others of calcite, and in some portions of the slide the appearance presented is almost that of a replacement of the felspathic rock by granular hematitic material. The boundaries, however, between the larger clear patches and the matrix are quite sharp both in hand specimens and in section. In the matrix, occasionally, are some very indistinct forms possibly the remains of a mineral of which the identity, however, cannot be made out. The rock is best described as a **breccia** composed of fragments of a highly felspathic acid rock cemented by a ferruginous (hematitic), and to some extent calcareous, cement.”

On the Golden Ridge property the dump of a shaft alongside the western margin of the ore-bearing rock shows a decomposed basic agglomerate; it is too decomposed to give its exact composition, but that it is undoubtedly fragmental can be seen in hand specimens. The rock consists of angular fragments apparently of fine-grained green-

stone of different textures, and though not accessible *in situ*, apparently lies alongside the graphitic slates

A typical agglomerate occurs two miles east of the 58-mile post on the east boundary of the Coolgardie Goldfield. This is unweathered and the varied composition of the different fragments is quite evident.

North-west of Mt. Herbert there is about 30 chains width of an indurated agglomerate composed of small fragments of even texture from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch across.

South-west of Mt. Hunt there are a number of bands of undoubted decomposed basic agglomerates up to three chains in width composed of fragments of varying textures from 1 inch to 18 inches long, very angular and in a decomposed basic matrix.

West of Mt. Hunt on the boundary of the greenstone and the porphyrite there is also an agglomerate, and between these last two occurrences frequent outcrops of agglomerates can be noticed in the porphyrite series.

PORPHYRITE (VOLCANIC).—These rocks are best represented at Feysville, where they are probably a continuation of the porphyrite belt west of Kalgoorlie. They are associated with agglomerates and slates, and appear to be derived from a volcanic series by metamorphism. They probably represent altered tuffs and acid lava flows interbedded with the neighbouring agglomerates and amphibolites. If such is the case some of them are greatly metamorphosed and the agglomerates have a porphyritic ground-mass. A good section of these rocks occurs at Feysville in a breakaway running eastwards from the Feysville Hotel. Here considerable thicknesses of decomposed porphyritic rocks occur interbedded with undoubted agglomerates and slates, and having the appearance of a volcanic series.

In places the porphyrite series is indistinguishable from true sediments which, in fact, portions of the series undoubtedly were originally. It is possible that in places there existed intrusive sills of porphyrite or porphyry; for example, the quartz porphyry in which occur the auriferous reefs of Golden Ridge.

A typical unweathered outcrop of porphyrite occurs in G.M.I. 3312E, three miles north of Feysville, close to the crossing of the Feysville track and the Woodline railway. It is described by Mr. Farquharson thus:—

[13088] A dark grey rock with numerous small pinkish phenocrysts of felspar and black phenocrysts of hornblende. There is a basic segregation in one portion. The section consists of numerous small and large idiomorphic crystals, some twinned on (100), of green hornblende, and some large completely kaolinised crystals of felspar in a ground-mass that is made up of small platy squarish and rectangular forms of turbid felspar with occasional round areas of quartz plates and occasional single plates of quartz. It would appear, therefore, that some of the crystals of the ground are but smaller forms of phenocrysts. Hornblende phenocrysts are very common, and felspar forms occasional, but the ground-mass is almost all felspar; quartz being rare, apatite in needles is not uncommon.

The rock is a weathered **hornblende porphyrite** with a felspathic ground mass showing a tendency to orthophyric structure.

According to this description this rock has decided affinities to a trachyte, as indicated by the orthophyric structure. The quartz, which according to the Petrologist is rare, is probably of secondary origin, in which case the rock might be classed as a hornblende trachyte.

This occurrence lends great support to the volcanic origin of the porphyrites, and this specimen (especially if the quartz were absent) has a trachytic tendency. The inclusions have every appearance of being xenoliths or included fragments, on account of their angular nature, sharp margin against the matrix, and their distribution along definite bands. It is probable that these xenoliths have been picked up from neighbouring bands of basic rock while the trachytic lava flow was poured out, or they may have dropped into the flow from a neighbouring volcano.

Another specimen occurring on the same line of strike as the above is described by the Petrologist thus:—

[13094]. Feysville G.M.L., 3941E.

"A much sheared grey-green rock with fairly numerous rounded and lenticular soft green chloritic patches that share in the prevailing schistosity. They appear very plentiful on the cross fracture.

"*The Matrix* consists of columnar and squarish phenocrysts of a greenish hornblende and occasional turbid phenocrysts of felspar in a microcrystalline ground-mass that is almost isotropic from decomposition, but in which small grains of quartz occur sporadically and rare grains of epidote. The felspar phenocrysts are altered largely to muscovitic mica scales, and have lost all optical properties so that their species is unascertainable. The structure is undoubtedly porphyritic. The opaque granular material, white by incident light, is doubtless a kaolinic product of the decomposition of felspar. Some of the larger quartz plates show irregular extinction. Needles of apatite occur in places. Rarely a large felspathic form has been completely altered and more or less replaced by brownish chlorite and biotitic flakes.

The rock is a much sheared and altered **hornblende porphyrite**.

The Greenish Patches: These are soft greenish, lenticular or rounded, and of all sizes, from minute to half an inch long. They have been affected by the same shearing action that has affected the matrix. In section they have generally rounded outlines and consist of chloritic and biotitic flakes with no clear line of demarkation from the matrix which extends normally to the edges of the flakes. In some there are needles of hornblende. They may be either basic segregations or enclosures. The characteristics of secretions or segregations are that they consist of the same minerals as the rock itself, but contain more of the first formed minerals, such as iron ores, sphene, etc., and they contain much more of the ferro-magnesian constituents than of the felspathic. In the present case the patches are almost wholly ferro-magnesian and consist of minerals which are easily derivable from the ferro-magnesian constituent of the rock by chemical and dynamic alteration, both of which have obviously acted strongly upon the rock. On the other hand, the shape of a few of the larger patches, producing, as it does, a kind of brecciated appearance in the rock, is suggestive of a xenolithic origin, though the composition of the patches is not that of a true xenolith. It is possible, of course, that the original magma caught up the fragments of a basic chloritic or hornblendic schist while yet molten, and that these patches are the partially digested remains, as happened in the case of the gabbro enclosure in the granophyre

in Skye. But in that case the assimilation of these fragments must have had a considerable modifying effect on the composition of the magma producing an increased basicity, which would therefore now be, in the solid state, more basic than when originally extruded, and portions of this original magma would be expected to be discoverable.

On the evidence, however, the rock is considered to be a sheared weathered hornblende porphyrite with a somewhat brecciated appearance due to the occurrence of numerous minute and larger soft greenish chloritic patches. The evidence in favour of their being segregations is scarcely definite, and, since according to the field evidence there is much in favour of their being xenoliths, they are more probably of such a nature."

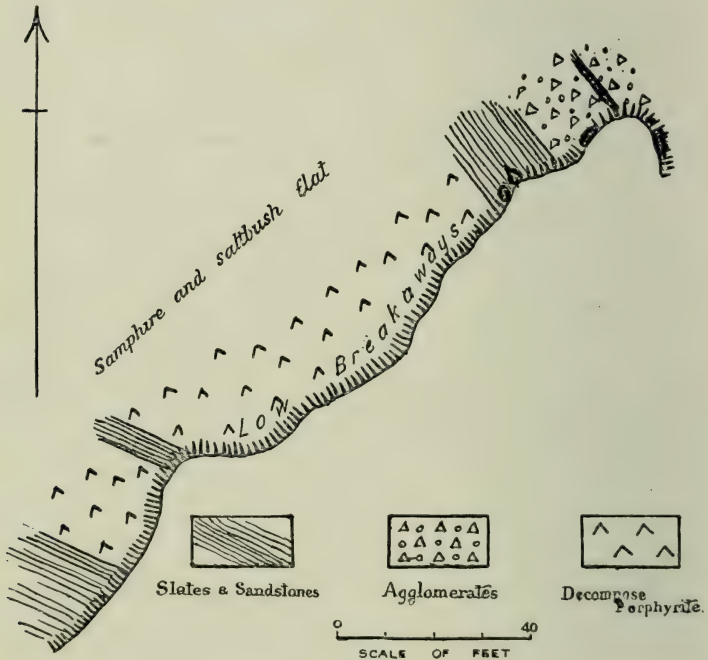


FIG. 1.

Plan of outcrop of porphyrite and sedimentary beds E. of Feysville.

This specimen is decidedly foliated and therefore the original internal structure is destroyed to a certain extent. It occurs in the same line of strike as [13088], and also contains crushed xenoliths. There is ample positive field evidence for the xenolithic or fragmentary origin of the inclusions, viz.:—

1. Occurrence in the same line of strike as undoubted agglomerates with a similar matrix.
2. On the same line of strike as specimen [13088] described above, of which it is a schistose variety.

3. In hand specimens it has the appearance of a conglomerate schist.
4. Weathered outcrops of the porphyrite reveal their bedded structure, and in some cases slates and sandstones do occur interbedded with the porphyrites. A very good section occurs to the east of the Feysville Hotel and the sketch plans herewith show the distribution of the beds (see Figs. 1 and 2).

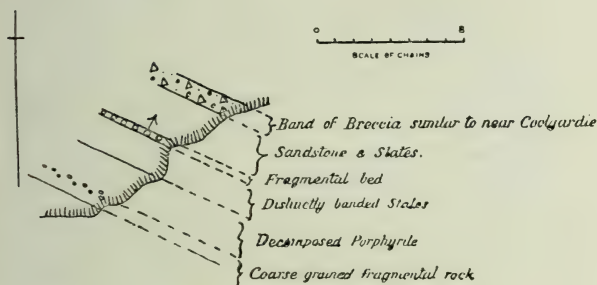


FIG. 2

Plan of outcrop of sedimentary beds S.E. of Feysville.

A similar decidedly bedded appearance is noticeable in portions of the porphyrite series to the west of Kalgoorlie, described by Gibson as sheared porphyrite and by Larcombe as sedimentary. The Feysville beds have been correlated with them as porphyrites, as the latter rock is the predominating type.

Agglomerates.—In the porphyrite series bands of agglomerates occur similar to those in the greenstones, except that the fragments are less basic, being composed for the most part of fragments of porphyrite. A very typical occurrence of a porphyrite agglomerate outcrops on the shore of Hannan's Lake east of Mt. Shea.

SEDIMENTARY ROCKS.—Some of these rocks, such as the interbedded slates, are necessarily included on the map in the volcanic series.

These rocks occur in narrow bands between the greenstone belts and occupy the valleys. Hence their outcrops are scarce, but sufficiently represented to establish their existence. There is a good development between Yilmia Trig. and the 27-mile post on the Widgiemooltha road. They consist for the most part of slates and fine grits and are metamorphosed to andalusite and mica schists by contact with granite.

On the western margin of the Horse Rocks granite-tableland, a further development of garnetiferous schists occurs, some of which contain traces of andalusite.

In the valley between the Golden Ridge Range and Kalgoorlie a wide belt has been mapped and both sides of the valley are represented by true sediments, slates and sandstones. The western boundary has been mapped by Gibson, and on the eastern side sedimentary outcrops can be frequently located right along the western fall of the Golden Ridge Range.

This series of sediments probably belongs to the same series as the porphyrites and the allied volcanic rocks, and represents a period of volcanic quiescence in that series.

There is a frequent occurrence of bands of graphitic slates which probably belong to the sedimentary series. These are not confined to the greenstone rocks, as graphitic slates also occur in the porphyritic rocks at Binduli.

These graphitic slates are especially well represented along the Golden Ridge Range. They are represented on the surface by ferruginous quartzites striking north-north-west in the greenstone. Their graphitic nature at depth is well shown in the Golden Ridge Mine.

On the eastern slope of the Golden Ridge Range and north of the Bulong road, light coloured slates are represented, at depth, in two shafts by highly graphitic slates, and on one dump the slate is decidedly elastic, having a highly fragmental character [13643] (*see* Fig. 3). Specimens from the dumps of these shafts have been described by Mr. Farquharson as follows:—

[13643]. A much sheared fine-grained gray-black rock with a considerable number of rounded and angular soft whitish small forms, some of which are pyrites and others give an alumina reaction. The black tone is undoubtedly due to graphitic carbon, but the origin of the whitish spots, which are all much decomposed, is uncertain. In section some appear to consist of an aggregation of small columnar feldspar forms that have been completely replaced by a mass of minute kaolinic and micaceous rods. Fragments of the graphitic material, however, occur in the larger aggregations in such shape as to suggest that they formerly wrapped round the forms. The origin of the rock is somewhat doubtful, but it appears to be a sheared **graphitic clay breccia** with much altered remains, some apparently of feldspar, others apparently of rock fragments, and some rounded pyritic forms."

Considering its field relations and the general geology of the locality as interpreted in this report, this specimen is best described as an agglomerate tuff. The fragments are angular to subangular, and the texture medium.

The origin of the graphite is doubtful and its presence is possibly due to one of two causes; either by decomposition of original carbonaceous material, or by subsequent impregnation with hydrocarbons. Almost all the graphitic slates contain pyrites, probably caused by the reduction by carbon of solutions of ferrous

salts. Considering its persistent occurrence in beds of sedimentary appearance, and being on field evidence apparently of such origin, it seems most probable that in the majority of cases the graphite is derived from carbonaceous material as an original constituent. It is probable that the forces to which these rocks have



FIG. 3.

Photo., C. S. Honnan.

[13643] Hand specimen from near 8-mile post, Bulong Road.

Neg. 1318.

been subjected was sufficient to obliterate all traces of organic structure which such carbonaceous material might originally have had; or the rocks may belong to a period during which no organic structure has been sufficiently developed for preservation in sedimentary deposits.

Some of the graphitic schists of the district have probably been formed by impregnation of the schists by hydrocarbons derived from pre-existing graphitic slates. An instance of this has been pointed out to me by my colleague, Mr. Blatchford, in the case of a porphyry dyke three miles east of Coolgardie, the enclosing walls of which are impregnated with graphite gradually merging into unaltered greenstone.

The typical graphitic slates of the district seem to correspond with the argillites of Southern India, as described by Dr. J. M. Maclaren, of which he states that

“there can be little doubt that these argillites represent original carbonaceous shales.”

In Drs. Maclaren and Thomson’s interesting account of the Geology of Kalgoorlie that appeared in the *Mining and Scientific Press* of America, there is no reference to the graphitic slates of the country around Kalgoorlie, except the occurrence in the Boulder area where reference is made to

“the graphitic schist due to local shearing of the Great Boulder albite porphyry dyke.”

From an examination of the country surrounding Kalgoorlie, for which I had better opportunities than Drs. Maclaren and Thompson, and from a cursory visit to the Golden Mile, it is my opinion that the majority of the outlying graphitic slates are sedimentary, and also, at least, some of those represented in the Golden Mile.

INTRUSIVES.—The following are the intrusive rocks represented in the region in the order of increasing antiquity:—

Newer gabbro (norite).

Granite.

Quartz-porphyry and porphyrite.

Amphibolised dolerite and gabbro.

Peridotite and derivatives.

Peridotite and Derivatives.—Owing to the difficulty in differentiating in the field between the derivatives of this rock and altered amphibolites, its boundaries could not be definitely traced at the time of this survey. The extent of the peridotite has, however, been roughly indicated on the map.

A typical specimen was obtained from two miles south-east of the 7-mile post on the Bulong road, and is identical with the Hannan’s Lake occurrence recorded by Mr. Gibson. Mr. Farquharson has described the specimen as follows:—

[13646]. An almost black fine-grained rock with reddish crust.

In section the rock consists almost wholly of rounded quadrilateral and polygonal forms, surrounded by a rim of magnetite and enclosing mostly colourless serpentine with fibrous structure, the fibres being set either at right angles to the rim or at right angles to cracks traversing the form. In some of the forms, apparently remains of the original mineral, are colourless plates

with high refractive index, and very strong birefringence and frequently with minute cracks. The mineral could not be examined optically, but is referred to olivine. Between the large forms occur isotropic material with rectangular crystals referable to augite. The rock is a black **serpentine** derived probably from a peridotite. It is the same rock as [13577], but is coarser grained, and less completely serpentinised.

Dr. J. A. Thomson has recorded a serpentine rock from this locality* at $6\frac{3}{4}$ miles east of Kalgoorlie on the Bulong road. This belongs apparently to the same belt and has the same characteristics under the microscope. Some of the talc-carbonate schists have been referred to by the Petrologist as possibly derived from a peridotite, but he favours their derivation from an amphibolite. Thomson, on the other hand, refers to the talc-carbonate schist of Golden Ridge and serpentine rocks of Kalgoorlie as derivatives from peridotites. On field evidence the talc-carbonate schists appear to be sheared derivatives of amphibolites.

Such a talc-carbonate schist occurs 30 chains north of the Quartz Blow on G.M.L. 3945E, and is described by Mr. Farquharson thus:—

[13650]. A **chlorite-talc-ferriferous carbonate rock** with a little quartz in grains, derived in all probability from an amphibolite, unless the talc owes its origin to olivine. In that case it may be derived from a peridotite, but of this there is no evidence. The appearance of the rock is more amphibolitic than peridotitic.

As regards the age of the serpentine rocks, if the carbonated schists are derivatives, it would show that the intrusions are pre-foliation and therefore the oldest intrusions in the field. On the other hand, the talc-carbonate schists may be altered amphibolites, and as they occur near the Boorara serpentine rock, have probably been altered by contact with the latter, in which case the serpentine rocks would be post-foliation. In the Feysville and Location 50 centres, however, the talc-carbonate schists are undoubtedly amphibolites altered by porphyry intrusions, and as porphyries occur on the Boorara Ridge also, the schists there have most probably a similar origin.

Amphibolised Dolerite and Gabbro.—These rocks are easily distinguished from the fine-grained greenstone by their coarser texture, and massive appearance. They generally have sharp boundaries and have the field characteristics of true intrusives.

No attempt has been made to map all these rocks except where they are specially conspicuous, and therefore some of these rocks will be found to occur unmapped and intruding the area mapped as fine-grained greenstone.

Good developments of this rock occur at Mt. Goddard and westward from Woolabar, also a number of broad dykes in Location 50 south of Feysville and $2\frac{1}{2}$ miles west of Golden Ridge. They are

* J. A. Thomson, Quart. Journ. Geol. Soc., Vol. LXIX., 1913, pp. 621-677.

here intrusive into fine-grained hornblende schists. The Petrologist has described specimens of the above as follows:—

[13658]. Two and a-half miles west of Golden Ridge.

An altered coarse-grained chloritised and amphibolised **quartz-dolerite**. Quartz is fairly common and largely interstitial.

[13654]. Weathered specimen from Kalgoorlie-Boorara Pipe Line, about two miles west of Boorara.

A grey medium-grained rock with thick red crust, and which consists in all section of granular calcite, chlorite scales and patches, and iron ore (leucoxene). The original structure has been almost completely obliterated, but some suggestion of a former ophitic structure led to the rock being classed as a much weathered chloritised and carbonated **amphibolised dolerite**.

The latter rock is associated with a volcanic agglomerate and points to the possibility of some of the dolerites being derived from volcanic rocks by metamorphism. This seems quite possible in view of the proved greatly metamorphosed character of the rocks of this area.

An example of a contact altered dolerite occurs in Location 50, associated with an intrusive porphyry, and is described by Mr. Farquharson thus:—

[13538]. Between G.M.L's. 13 and 14, Location 50.

A coarse-grained amphibolised **quartz-dolerite**, with feldspars altered to a granular epidotite mixture, and with some interstitial quartz. The amphibole is the pale green very fibrous uraltic variety. A flake or two referable to biotite also occurs.

This specimen shows large idiomorphic hornblende in hand specimens and has a knotted appearance. In view of its proximity to the porphyry dyke the knotted and schistose structure has probably been induced by contact metamorphism. A very similar rock occurs on the east spur of Mt. Goddard, also in proximity to porphyry dykes and is described by the Petrologist thus:—

[13548]. A greyish-green somewhat coarse-grained rock with large plates of almost colourless hornblende and feldspar forms now completely altered to granular material of which the constituents are difficult to make out, but of which kaolin and zoisite form part. There is a little quartz in irregular plates. The large crystals are pale greenish to yellow in pleochroism with an extinction angle that places them as an amphibole. They are uraltic forms derived doubtless, as in the case of the smaller crystals, from original augite. The structure is indefinite. The rock is an **amphibolised doleritic gabbro**, coarse-grained with much altered feldspar.

Quartz Porphyry and Porphyrite.—The porphyry rocks are very widely distributed and it has been found impossible to map all of them in the area. The most conspicuous outcrops occur—

- (a) Three miles north of Feysville;
- (b) In the southern portion of Location 50;
- (c) At the Emu holes on the Widgiemooltha Road;
- (d) The Golden Ridge Gold Mine; and
- (e) Near the 6-mile post on the Bulong Road.

A great variety in texture and composition is apparent from an examination of the different outcrops.

At Golden Ridge the quartz reefs occur in a porphyry mass which does not appear to be intrusive but a sill or flow. This rock is probably older than the general run of porphyry occurrences. It has, however, been placed in this group for convenience.

There are four varieties represented in the area—

1. Coarse-grained quartz porphyry;
2. Fine-grained quartz porphyry;
3. Granite porphyry; and
4. Biotitic granulitised quartz porphyry.

On the Lake road from Kalgoorlie to Feysville, a little over three miles north-north-west of the Feysville townsite, there occurs a large boss of coarse-grained quartz porphyry of an undoubted intrusive nature, as arms can be traced extending from the central boss into the adjoining schists; a typical specimen of this is described by Mr. Farquharson as follows:—

[13098]. A medium-grained grayish granitic rock with a dark chloritic sheen on some portions of the surface. In section, there are large phenocrysts of clear quartz usually with more or less rounded margins, and in places with irregular extinction due to strain, and large turbid phenocrysts of mostly lamellated feldspar in a microcrystalline ground of quartz and feldspar that has a faint reddish tinge, due to red oxide of iron round the mosaic grains. Here and there are flakes and flaky aggregates of brownish biotite, rarely the larger flakes exhibit saagenitic webbing. Owing to the turbidity the species of feldspar could not be made out exactly, but it is mostly about oligoclase. The margins of many of the feldspar phenocrysts appear slightly granulitised. There are biotitic and other inclusions in the quartz and decomposition of the feldspar has given rise to kaolin and muscovitic scales. The biotite has in places been chloritised. The rock is a coarse-grained **quartz-porphyry**.

A granitic phase of this rock is described thus:—

[13097]. A medium-grained grey granite with numerous flakes of a pale brown biotite. In section there are large columnar clouded feldspars partially granulitised on the margins; large clear quartz crystals cracked in places and irregular flakes of pale yellow-brown biotite of which some show saagenitic webbing. Quartz and feldspar occur in a mosaic ground of feldspar crystals, giving the rock a faint porphyritic appearance. The feldspar is mostly an acid plagioclase. The rock is a **biotite granite**.

This specimen was taken from the dump of a shaft on abandoned G.M.L. 3875E, and is apparently a granitic phase of the porphyry. This is important as proving a connection between the porphyry and granitic rocks of the district.

The fine-grained porphyry occurs in the southern portion of Location 50. The only apparent difference between this and the Feysville occurrence is that the latter is of much coarser grain, while the Location 50 porphyries are almost felsitic.

Structurally both the fine and coarse-grained varieties are intrusive into the greenstones and produce the same effect on the contact rocks.

The effect of the porphyry on the greenstone is to produce a development of large idiomorphic hornblende giving the contact rock a knotted appearance. This is clearly seen between G.M.Ls. 13 and 14 in Location 50, and on Mt. Goddard. According to the petrologist another effect is the feldspathisation of greenstone schist. West of the Battery at the north end of Location 50 a porphyry dyke in massive greenstone has altered the greenstone at the contact, resulting in the production of acicular crystals of hornblende accompanied by feldspathisation, which is quite noticeable in hand specimens. The ground-mass has at the same time become felsitic in appearance.

Two specimens of the fine-grained variety from the Hampton Boulder Mine (Speakman's Workings) have been described by the petrologist thus:—

[13581]. No. 1. A **quartz-porphyry** slightly coarser than specimen [13568] (from Golden Ridge) with kaolinised and micacised feldspars, some nests of muscovite, and a platy crystalline ground-mass. Some of the quartz phenocrysts show undulose extinction due to strain.

[13581]. No. 2. Large crystals of plagioclase partially granulitised, kaolinised, and micacised, some irregular plates of quartz with irregular extinction appearing as if partially sericitised, and many scales of white sericitic mica. A partially **granulitised quartz-porphyry** with quartz veinlets and much mica.

This rock is almost felsitic in places. A band parallel with the main Hampton Boulder porphyry and a few chains to the east has been described thus:—

[13605]. A greyish-yellow aphanitic rock from a much weathered surface. There are numerous very irregular and frequently angular plates of quartz and feldspar in a fine crystalline—in places micro-crystalline—ground-mass. The extinction in most of the quartz is very irregular, there is secondary lamellation as well as cracks and faults, in many of the feldspars, and the character of the larger forms is that produced by detrital origin or by severe crushing. There are a few flakes of muscovite and grains of magnetite and hematite. The rock is most probably a **crushed felsitic quartz-porphyry**.

A fine-grained porphyry occurs on the Widgiemooltha road as part of a mass of porphyry which varies considerably in texture. The following is a petrological description of a specimen collected at 34 miles from Coolgardie on the Widgiemooltha road. In hand specimen it has a felsitic appearance.

[13590]. A gray very fine-grained rock, small nests of brown-yellow and colourless mica, and apparent rough alignment in the coloured constituents and with nests of greenish black tourmaline on the surface. In section, there is a minute mosaic mass of clear quartz, and more or less clouded feldspar plates, with numerous small flakes of colourless muscovite, brownish-red pleochroic biotite, grains of calcite and some greenish isotropic flakes of chlorite derived probably from a biotite. There are no clear remains of large feldspar crystals. The feldspar grains are all kaolinised and are rather less common than the quartz. The structure of the rock is essentially granitic. A minute rod apparently of tourmaline was observed. The rock is a finely granulitic quartz feldspar-mica rock probably derived from the granulitisation of a fine-grained **quartz-porphyry**.

The Binduli-Wongi porphyry belt occurs below the Red Hill-Horse Rocks road, and floaters can be found near the 29-mile post.

An uncommon variety of porphyry occurs at the Emu Rocks, 10 miles north of Widgiemooltha. This is a biotitic quartz porphyry and in hand specimens has a mottled appearance owing to the numerous small nests of biotite it contains. It is described by the petrologist as follows:—

[13602]. A yellowish-grey rock with phenocrysts of felspar and many small nests of biotite. The rock consists of large irregularly outlined and very turbid phenocrysts of felspar showing both Karlsbad, albite, and pericline twinning, rare and very irregular rounded crystals of quartz with small and large flakes of brownish biotite and some patches of calcite and flakes of greenish chlorite, in a finely crystalline ground-mass of quartz and felspar and micaceous flakes. The quartz shows irregular extinction and has apparently been slightly resorbed and granulitised at the margins. Kaolin and mica are visible in the felspars and grains of iron ore are not uncommon. The structure of the rock is porphyritic, though the irregular character of the phenocrysts resembles that in granitic arkoses. The rock is a partially **granulitised quartz-porphyry** with numerous biotite nests.

At Golden Ridge, owing to the occurrence of auriferous quartz reefs in it, the porphyry is of special importance. As stated above, this rock is classed as a crushed sill or flow and is only placed under the heading of intrusives for convenience of description.

It is a pale olive-green rock of medium texture and a rather felsitic appearance but with a decidedly porphyritic structure and containing blebs of quartz. A typical specimen [13520] is described below by Mr. Farquharson.

Since writing a preliminary report on the Golden Ridge Centre, some interesting results have come to hand from the petrologist following the examination of representative specimens of bore cores from the Golden Ridge Mine. It appears from these results that porphyry exists outside the ore-bearing rock, but quite distinct in appearance from the ore-bearing porphyry.

The Golden Ridge porphyry is therefore divided into two distinct types:

- 1.—A pale olive-green quartz porphyry;
- 2.—A dark-green chloritic quartz porphyry.

No. 1 is ore-bearing and all the auriferous reefs hitherto discovered appear to be confined to it. In the south-eastern portion of the porphyry formation there is a change to the dark green chloritic variety, and a corresponding absence of auriferous reefs. No. 1 is bounded on the east by tale-chlorite schist and on the west by graphitic slates. No. 2 occurs west again of the graphitic slates and has so far been found barren of payable quartz reefs or of reefs of any size.

The following is Mr. Farquharson's report on the specimens of bore cores submitted. The numbers of the specimens can be referred to on the plan and sections of the mine (*see* Plates V. and VI.) :—

With a few exceptions, these cores are so very much altered, especially chemically, that the examination both of their structure and their composition is attended with much difficulty. Owing to the general minuteness of grain and the alterations, in most cases it has been impossible to determine accurately the structure of the ground-mass, and in some cases only general indications of the structure of the rock are afforded.

As a rule, however, there are remains of original feldspars that appear to have had a phenocrystal habit. The specimens can be considered under two heads :

(a) the light coloured rocks ;

(b) the greenish rocks.

(a)—The light coloured specimens show phenocrystal feldspars and quartz crystals and are undoubtedly to be classed as quartz porphyries. In one [13517] there are black needles of chloritised hornblende, and in another [13513] there appears a grading into a dark greenish chloritic facies in which porphyritic feldspars also appear.

[13520]. No. 8 Bore, 400ft. level, at 104 feet.

The country rock of the mine. A yellowish-white rock apparently slightly sheared. In section it proves to be a somewhat sheared **kaolinised and mica-cised quartz-porphyry**, with squarish quartz phenocrysts and large kaolinised feldspar phenocrysts, in a very turbid kaolinic microcrystalline ground-mass. A few of the quartz crystals show slightly irregular extinction and the feldspars are either micacised or kaolinised. There was no reaction for calcite.

[13517]. No. 1 Inclined Bore, 400ft. level, at 191 feet.

A whitish hard aphanitic rock with occasional feldspars and some black needles. In section the rock consists of large phenocrysts of kaolinised feldspar in a minutely grained ground-mass of quartz and feldspar obscured by much granular material that is largely kaolinic but in places calcite. Rarely some large rectangular crystals green and pleochroic occur that are referred to chloritised hornblende. There are occasional quartz veinlets and some calcite. The rock is a kaolinised slightly **carbonated quartz-porphyry** with hornblende needles.

[13513]. No. 1 Inclined Bore at 128 feet.

In hand specimens a gray rock with white phenocrysts of feldspar and some of colourless quartz. In section there are very large phenocrysts of turbid kaolinised feldspar and a few of quartz in a fine-grained ground-mass of quartz and clouded feldspar plates, and much granular carbonate (calcite) in grains and plates. There is a passage into a dark green chloritic facies in which white feldspar phenocrysts are also recognisable. The rock is a **quartz-porphyry** kaolinised, carbonated, and in places chloritic.

(b.)—The greenish rocks appear at first like sheared chloritic amphibolite that has been carbonated. In almost all cases, however, large altered feldspar forms are discernible of distinctly phenocrystal habit, and so far as observed there is no clear evidence of any former ophitic or sub-ophitic structure in the relations of these feldspars to the rest of the rock. Rather does the structure in nearly all cases conform to that of porphyritic rocks. Quartz phenocrysts are as a rule not in evidence, but in a few cases some rounded forms of quartz mosaic probably represent original quartz plates that have been granulitised, and in one case [13524] quartz phenocrysts of very definite outline do appear associated with feldspar phenocrysts. [13524] moreover, is distinctly chloritic and is the greenest and most chloritic of the green specimens. It is undeniably porphyritic. The origin of the chloritic scales in these rocks is not altogether clear unless the hornblende needles in [13517] afford the clue. The green specimens moreover, appear in general to be more sheared than the lighter coloured rocks. On the whole, except in the case of [13524], the evidence of

the origin of these green specimens is, owing to the large amount of alteration that has taken place in them, not entirely convincing, but the characters of [13524], the occurrence of the large porphyritic and phenocrystal feldspar forms, and the occurrence in [13515] of some remains of a microcrystalline ground-mass of quartz and feldspar, lead to their being regarded as chloritic, carbonated, and micacised phases of a porphyritic rock of varying composition. As already stated, evidence of a doleritic origin is not clear.

[13524]. No. 8 Bore, 400ft. level at 140ft.

A soft greyish-green somewhat sheared fine-grained rock. In section there are large and small phenocrysts of clear quartz and large and small phenocrysts of twinned feldspar that has been largely kaolinised both in a cryptocrystalline ground in which minute greenish chlorite scales, sericitic and kaolinic fibres and calcite grains can be distinguished, occasional calcite crystals occur both in the ground and in the feldspar. The structure of the rock is decidedly porphyritic. Shearing action on it is shown by cracks in the quartz, and by the pressure of strings of minute micaceous scales. Despite the sheared and green chloritic appearance, the rock is put down as a **chloritic quartz-porphyry**.

[13522]. No. 3 Bore 400ft. level at 125ft.

A dull greyish-green somewhat aphanitic rock of fine grain with veinlets of quartz. In section there are large columnar completely micacised feldspars in an opaque, yellowish-green ground-mass that is white by incident light, and contains granular calcite. There are, moreover, rounded areas of minute mosaic that may represent granulitised quartz phenocrysts. Sericitic mica occurs not only in the feldspars but largely in strings undulating and drawn out in parallel directions and associated apparently with some isotropic chloritic strings. The rock is much altered, but appears to be porphyritic. It is put down as a much altered **chloritic muscovitic and carbonated porphyry**.

[13519]. No. 1 Inclined Bore, 400ft. level at 40-70ft.

A dull greyish-green much sheared rock with whitish remains of porphyritic feldspars. The weathered character of the rock is obvious in section. There are, however, micacised and kaolinised remains of squarish and columnar feldspar phenocrysts with a finely granular largely kaolinic ground sheared against them. The structure is porphyritic phenocrystal rather than ophitic, and the rock is classed, so far as its condition permits, as a much altered, sheared, **chloritic porphyry or porphyrite**. Quartz phenocrysts were not recognised.

[13515]. No. 8 Bore, 400ft. level, at 352ft.

Is now in general only a granular mass of calcite grains with probably chloritic scales, but in one portion of the slide a microcrystalline mosaic is visible composed of quartz and clouded feldspar plates and very similar to the ground in normal quartz porphyries.

[13516]. No. 1 Inclined Bore, 400ft. level, at 80ft.

Is very much altered, carbonated, etc., but some turbid columnar and somewhat platy feldspar forms are still visible, and some quartz plates appear as if constituents of ground-mass.

[13514]. No. 3 Bore, 400ft. level, at 190ft.

Sheared structure is very noticeable, and there are large altered (micacised) feldspar forms of phenocrystal habit in a mass that in places at any rate, consists of small quartz plates and grains of carbonate.

There is a syenitic variety of porphyry on the Widgiemooltha road about 35 miles from Coolgardie. Its structural relations could not be made out owing to its boundaries being masked by superficial

deposits. It is probably a phase of the large development of porphyry in this part of the country. Mr. Farquharson has described a specimen of this rock as follows:—

[13600]. A yellowish-grey medium grained rock consisting of yellowish feldspar and small crystals of dark-green hornblende. Briefly, the rock consists of large, almost completely clouded, and very irregularly outlined crystals of feldspar, and fewer crystals of a green pleochroic hornblende in a granulitic or mosaical ground-mass in which both feldspar and quartz can be distinguished. Many of the feldspars have broken boundaries, and have, in many cases, been granulitised, while many of the hornblende plates are perforated. Owing to their clouded nature, the feldspars were difficult to determine, but there are forms exhibiting the cross-hatched appearance of microcline, others showing the albite lamellation of a plagioclase, and others with karlsbad or no visible twinning. Some feldspars appear to have a secondary twinning lamellation, produced by strain. The rock is of rather peculiar type. Part of the ground-mass would appear to have been produced by granulitisation of some of the feldspar; on the other hand, the larger feldspars appear distinctly as phenocrysts, although their boundaries are generally indistinct and somewhat granulitised. The rock is either **an acid-quartz-feldspathic facies of an amphibolite, or an acid quartz-syenite porphyry.**

A more basic variety of the porphyry occurs south of Woolabar in Location 48. This occurs as a dyke intrusive into amphibolite. Xenoliths of amphibolite occur in one portion of the intrusive and have apparently been caught up and partially absorbed, giving the rock a more basic composition. A broad band of apparently the same magma, but unassociated with amphibolite xenoliths occurs close to the above, and a specimen has been described thus by the petrologist:—

[13598]. A **quartz-porphyry** with rare quartz and numerous feldspar phenocrysts, and a few brown biotite plates with numerous rods and scales of brownish and muscovitic mica. Feldspars kaolinised and a biotitic segregation present.

It is possible that from this the more basic variety has been derived. The latter is described as follows:—

[13591]. South boundary of G.M.L. 2, Location 48.

A gray porphyritic rock of medium grain with phenocrysts of feldspar and flakes and small nests of biotite. There are large phenocrysts of more or less turbid feldspar and flakes and flaky aggregates of brownish biotite in a fine ground-mass composed largely of small irregular plates—some elongated—of feldspar and grains of quartz. The ground, as a rule, is microcrystalline, and owing to the weathering of the rock, and the fineness of the grain, the constituents of the ground are difficult to resolve. Further obscuring of the ground is caused by flakes, rods, and minute scales of biotite. Many of the larger feldspar phenocrysts exhibit distinct zonal structure, while some appear to exhibit no twinning. The structure of the rock is distinctly porphyritic. The phenocrysts are all of feldspar, and the prevalence of zonal structure suggests the presence of andesine. The rock is classed as a **feldspathic porphyrite** or a **quartz-porphyrite**, with numerous feldspar phenocrysts and with quartz in the ground-mass.

Granite.—The south-western portion of the country is occupied by a high granite tableland representing the eastern margin of the great granite tracts lying between the auriferous belts of Coolgardie

and Southern Cross. The contact of the granite with the Coolgardie auriferous belt is very irregular and shows numerous invasions into the latter by tongues of the former. No detailed study has been made of the different phases of granite in the area. It belongs, however, almost exclusively to the massive plutonic variety of medium-grained biotite-granite. No occurrence of gneiss was noted. The granite is apparently of two ages; the older basement granite, and later intrusive granite. The latter is most extensively exposed as occurring along the contact.

Contact metamorphism has been extensively developed around the granite area as is shown by the presence of garnetiferous, andalusite, micaceous, and knotted schists, extending in some cases for considerable distances from the actual contact; there is a marked diminution in these contact minerals as the distances from the granite increase.

The older basement granite has probably been formed by sub-crustal fusion of an older acid basement series of unknown character.

This large tract of granite is for the most part covered by sand and scrub, and forms an elevated sand plain extending south-westwards from the Horse Rocks, on the Coolgardie-Widgiemooltha road. Around the borders of the mass there are numerous pegmatite and fine-grained granite dykes penetrating the adjoining schists.

These dykes generally arrange themselves parallel with the strike of the foliation which is generally parallel with the contact. If followed into the schists a pegmatite dyke is seen to thin out and change into a glassy quartz, and finally die out. In the opposite direction the dyke widens and changes into greisen and granite when it joins the main granite mass. This can be well demonstrated on the Coolgardie-Widgiemooltha road, which passes over a number of such pegmatite dykes near the 24-mile post.

Some of these dykes contain an abundance of almost colourless platy mica, which if procurable in sufficiently large flakes, would be of commercial value.

Tourmaline occurs in the pegmatites and the conditions seem very favourable for the occurrence of such minerals as tin oxide, amblygonite, scheelite, wolfram, and molybdenite.

An isolated boss of granite also occurs in the greenstone series in Location 48. This appears to be an inlier, and is associated with numerous granite dykes, good instances of which occur at Red Hill. This occurrence undoubtedly indicates that the granite complex is at no great depth below the surface to the south of Kalgoorlie.

A nucleus of granite was referred to above (p. 27) when describing the porphyries, as occurring in a porphyry boss north-north-west of Feysville. This may be the outer fringe of the underlying granite consolidated in the act of absorbing the porphyry.

There appears to be no definite contact between the granite and the porphyry, and it may be that the porphyry is merely a stage in the formation of granite by regional metamorphism. This would account for the occurrence of porphyry in less metamorphosed areas some distance from the known granite outcrops.

The younger age of the granite than the porphyry is supported by the occurrence of granitic dykes west of the Hampton Boulder porphyry dyke. This granitic dyke is massive and has apparently not been subjected to movements which the porphyry undoubtedly has, as shown by shear planes in the latter. The granitic dyke also strikes across the foliation of the country, having occurred very late relative to the other dykes of the district.

Newer Gabbro (Norite).—This rock represents the youngest of the basic intrusives, and occurs as a dyke running across the strike of the country. This dyke has its western extremity at Wongi, and can be seen persistently outcropping in an east-north-easterly direction for 10 miles in an almost straight line. On the same line of strike it outcrops again north of the Simplex and Duplex hills and appears to emanate from a hypersthene-gabbro occurrence located by Blatchford four miles south of Bulong.

This dyke is petrologically and structurally similar to a dyke recorded by Campbell at Norseman. It is, like the Norseman occurrence, characterised by an absence of any internal crushing, showing that the rock has not been subjected to the great pressures and temperatures to which the older rocks of the district have been exposed, and it can be safely said that it is one of the latest phases of intrusion in the district. No later dykes cut across it. As to whether it is younger than the granite, there is no direct evidence yet forthcoming. That it is younger than the porphyry can be seen at Wongi, where the dyke cuts across the porphyry rocks. It is probably contemporaneous with the basic dykes that intrude the granite of the Darling Ranges.

The following is a petrological description of a specimen which is not, however, a typical representative of the whole dyke:—

[13090]. One mile 65 chains north of S.E. corner of Location 50.

Consists largely of more or less columnar large crystals of somewhat turbid feldspar mostly strongly twinned on the albite plan, with clear shapeless forms of quartz in the interstices, and some irregular crystals of brownish augite. These latter have in some cases been altered to a brownish-red chloritised form; in others a crystal exhibits twinning on the orthopinacoid and "salite" structure; and rarely there is a form with schiller structure. Needles of apatite also occur. The structure is coarse granular, and the rock is a quartz gabbro. It probably varies somewhat in mineral composition in different parts doubtless merging into a norite.

THE KURRAWANG SERIES.

The Kurrawang conglomerate schists represent the youngest rocks in the area. There is no obvious unconformity on the field, but the Kurrawang series contains detrital material belonging to the neighbouring porphyries and greenstone schists, and are decidedly different in character from the older series.

Structural features can still be made out in the Kurrawang rocks, as is instanced by the huge synclinal fold developed there, while none such is evident in the older rocks.

At Mount Jackson, however, there is a series of conglomerates similar to the Kurrawang series, but resting decidedly unconformably on greenstone, quartzites, dolerites, and porphyries allied to the Kalgoorlie series.

These rocks are most extensively developed between Kalgoorlie and Coolgardie, and have been dealt with in detail in Bulletin 56, *q.v.*

In the area embraced by this report, there is a recurrence of the Kurrawang series south of the Horse Rocks-Red Hill road, and there represented by crushed conglomerates and arkoses. A good outcrop can be seen in a well on Mabie's Old Homestead, about three miles west of Red Hill.

RECENT (SUPERFICIAL.)

Between the superficial deposits and the underlying rock masses there is a big geological break. The superficial deposits rest unconformably on the upturned edges of the ancient metamorphic rocks and their associated intrusives. They are still in the process of formation.

Alluvium.—This occurs both in the oldest and youngest of the recent deposits and occupies large tracts of country. In open country it is covered by aeolian material. In hilly country it occupies the flats and valleys between consecutive ridges. It is composed of a mixture of clay, sand, and ironstone gravel, which varies with the composition of the surrounding rocks. Thus in granitic and sandstone country the alluvial is sandy, while in greenstone country it is a ferruginous clay, sometimes gravelly, through denudation of the ironstone concretionary laterite, which sometimes caps the greenstones.

In hilly country the alluvium is fairly shallow, while in open country it must be of a considerable depth.

The geology of considerable areas of country is masked by alluvial deposits.

Dry Lake Deposits.—The Dry Lakes are composed of a clayey material with a white deposit of salt and gypsum which never reaches any thickness owing to rapid disintegration and scattering by the wind. The salt lakes generally occupy the depressions and probably contain a great depth of alluvial material. Moisture is held in these depressions for a long time after rain, and is slowly evaporated from the damp surface of the lakes.

The salt lake area is represented by Hannan's Lake which covers an area of, roughly, 20 square miles. Its northern extremity is at Lakeside, and at Feysville it pinches to a string of samphire flats trending towards Lake Lefroy. Its western margin is bare and rocky, being composed of strings of breakaways. Marked features of the lake country are the sand dunes and the banks of "kopai" on the south-eastern margin. Kopai is a local name which is applied to material which is principally composed of blown gypsum, salt, and sand.

The sand dunes are succeeded by salt bush flats, then mallee and spinifex country which extends for miles southwards, gradually sloping upwards to hilly country.

A very marked feature on the western shore is the closeness of bed rock to the surface of the lake. This is apparently due to the undercutting of the shore, and the "migration"* of the lake to the north-west by the blowing of material from the north-western shore to the sand dunes on the south-east. The bed rock is kept level by moisture. A beautiful instance of this occurs in the Johnson Lakes at Bremer Ranges, where, on the north-west shore, the lake surface corresponds with bed rock for some chains from the cliffs and shows an excellent horizontal section of the rock structure (see Fig. 4).

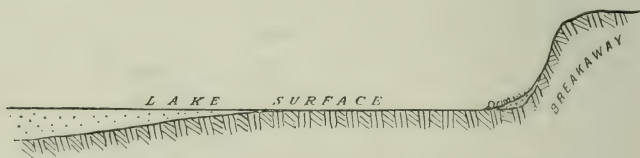


FIG. 4.

Section across western shore of Lake Country.

Aeolian Plains.—The aeolian sand plains constitute sandy slopes on the southern and south-eastern margin of the lake country, and are covered with mallee and spinifex. They extend over a great area of country and are no indication of the character of the underlying rocks.

Travertine.—This occurs sporadically as a superficial crust of limestone on the flanks of ridges forming a cement capping to decomposed country rock.

* J. T. Jutson. Bull. 61: The Physiographical Geology of Western Australia.

Laterite.—Some of the laterites are probably the youngest of all the superficial deposits. They are very extensively distributed over the area, and range in composition from an almost wholly silicious to a highly ferruginous variety, according to the acidity or basicity of the underlying rocks.

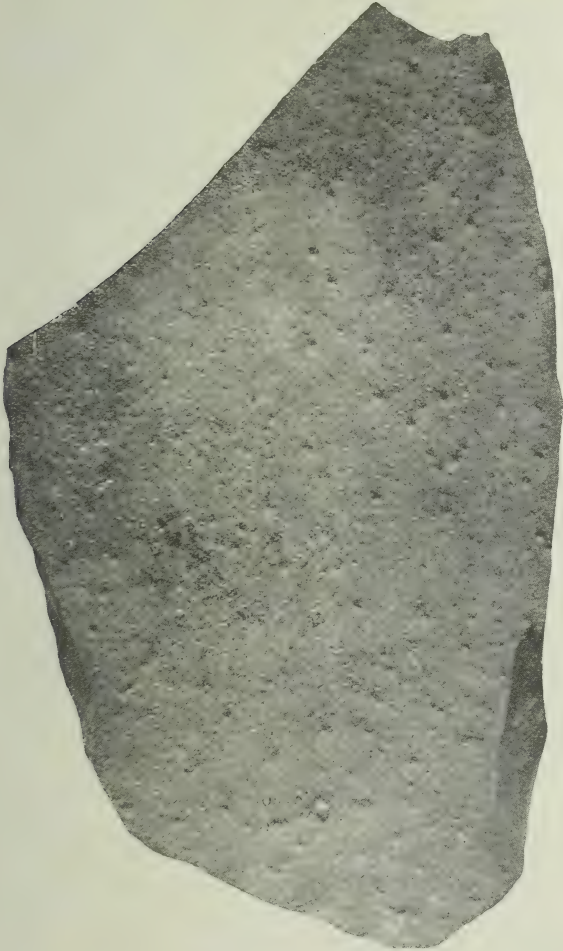


FIG. 5.

Photo., R. H. Irwin.

[13651] Alluvial Cement at 6½-mile post on Bulong Road showing rain spots.

Neg. 1319.

Sometimes the alluvium is indurated into a rock which has every appearance of a laterite or cement. This often happens in the case of the detrital material or talus that accumulates on the sides of a hill. Such an occurrence may be seen at the 6½-mile on the Bulong road. Its surface is pitted as though by rain spots (see Fig. 5). The alluvium has apparently been soaked by rain and then

baked by the sun, and by evaporation has been formed into a laterite which still preserves the marks made by the rain drops. A specimen from this occurrence is described by Mr. Farquharson thus:—

[13651]. Six miles 30 chains on Bulong road.

A brown-red rock with minute fragments of quartz in a granular haematite matrix. There are a few flakes of yellowish mica.

In section there are squarish and angular quartz fragments, and fragments of minute quartz mosaic with rare irregular forms clouded by fine dust which may have been felspar, all cemented by much red hematitic clayish material. There is no evidence of secondary deposition of silica on the margins of the quartz, and the grains of the latter are comparatively few and the intervals of clayey material between them considerable. There are rare faint outlines of forms which may have been ferro-magnesian fragments. The structure and composition of the rock is that of a ferruginous (hematitic) **quartz-grit** of detrital laterite origin. It has not been, and is not now, a sedimentary sandstone.

V.—STRUCTURAL GEOLOGY

A study of the structural relations of the rocks of the area, covered by this report, is attended with considerable difficulty, chiefly on account of the scarcity of that class of outcrop from which evidence of structure can be obtained; also on account of the great dynamic and metamorphic forces to which the country has been subjected, which has resulted in a crowding together, a squeezing, and a foliation of the sedimentary and volcanic rocks. Of folding there is not sufficient evidence to define any definite synclinal or anticlinal axes, or to indicate whether the beds are repetitions of portions of the same horizon of sediments (isoclinal) or a continuous series of different horizons (major folds). But by analogy with the occurrence in the district of a very wide synclinal in the apparently younger series at Kurrawang, and the appearance of these latter rocks of having been subjected to the same distorting forces, it is most probable that the older rocks also represent major folds the presence of which has been entirely masked by the development of vertical foliation planes across which the bedding planes originally existed.

On account of the unavoidable confusion of cleavage and bedding, dips of sedimentary rocks cannot always be accurately measured, therefore reliable dip measurements are scarce, and in almost all cases, are above 60° with a general tendency to the east.

The structural features of this area are as follows:—

(a.) **FOLDING.**—Sedimentary rocks are undoubtedly present, but their folding, for reasons stated above, cannot be definitely determined, though analagous occurrences in the field point to a series of major folds.

(b.) **FOLIATION OR CLEAVAGE** has been induced in the rocks of the area by the great regional lateral pressure which has left its mark on all the rocks of the Eastern Goldfields.

The foliation is more pronounced along certain bands of country than others, although an incipient foliation occurs even in massive rocks. The foliated rocks occupy the lower portions of the country and the flanks of the ridges. The foliation can be seen in almost any outcrop, and in all cases is almost vertical.

(c.) SHEARING.—There is evidence of widespread shearing of the rocks, and it is along the shear planes that fissuring occurs, providing spaces for the formation of quartz reefs and lodes. The shearing in the massive rocks appears to take place parallel with the general strike and incline at a steep angle in two directions, one dipping east and the other west. In the foliated and schistose rock the shearing seems to occur along the planes of foliation, resulting in the formation of slickensided faces. The force that produced shearing in the massive rocks has emphasised the schistosity in the schistose rocks.

(d.) PLANES OF PARTING.—Probably the latest formed breaks or cracks in the rocks. In massive rocks they occupy three planes approximately at right angles to one another: two vertical planes and one horizontal. In the foliated rocks the plane of foliation serves as one of the vertical planes of parting. The partings form smooth clean-cut faces and correspond with the "heads" found in underground workings where they are of great assistance in breaking ground. They are also the cause of many accidents when blocks of ground bounded by them are not properly supported.

(e.) FAULTING.—This is the most important structural feature from an economical point of view, since upon the nature of the faulting in a district depends many of the practical problems of mining.

Referring strike and dip to the schistosity of the rocks, there are apparently two main types of faults in the district:—

(i.) Strike faults. Reversed. Both pre-mineral and post-mineral;

(ii.) Dip faults. Reversed. Mostly post-mineral.

(i.) The *strike faults* are due to compression and have, in some cases, acted as channels for the circulation of mineral-bearing solutions, thus resulting in the formation of ore bodies. They generally have a strike roughly parallel with the general schistosity or foliation of the country and have slickensided walls.

They dip both to the east and west at a steep angle. The reefs of the Golden Ridge Mine have probably been formed in fault fissures of this description. They are mostly reversed faults.

There is no evidence of fold faulting owing to the advanced stage of the folding. Most of the faults are compression faults, with small displacements as far as the mines are concerned, as is shown by the displacement of the reefs.

(ii.) *Dip Faults*.—These apparently are of much later origin than the former type of faults, and, where observed, appear to be also reversed faults. This type of faulting is very prevalent on the Golden Ridge Mine, but with small displacements.

As regards faulting on a big scale there is no direct geological evidence; the physical features, however, along the Kurrawang Lakes strongly suggest the existence of a major fault plane.

Dr. J. Malcolm Maclaren and Dr. J. Allen Thomson, in a paper on *The Geology of the Kalgoorlie Goldfield*, which appeared lately in the *Mining and Scientific Press*, of America, refer to a thrust plane south of Kalgoorlie, which they call the Mount Monger Thrust Plane. Although the country surrounding the Kalgoorlie and Boulder mines has already been gone over roughly by Dr. Maclaren, it is unfortunate that no map has been published with the report, but referring to overthrust faults, Drs. Maclaren and Thomson say:—

One thrust-plane may however be made out passing south-east from Mt. Robinson to a few miles south of Feysville (where the shearing that accompanied it is quite evident) to Mt. Monger in the south-east. The pressure generating this overthrust was horizontal and from the south.

I am unable to agree with Drs. Maclaren and Thomson, who no doubt have not had the same opportunities as myself for detailed mapping of the outlying district, as to the existence of the Mount Monger Thrust Plane, for the following reasons:—

After a thorough examination of the localities referred to above, no evidence either topographical or geological is forthcoming that would indicate or support the existence of such a fault plane. Drs. Maclaren and Thomson, referring to the shearing that accompanied the thrust as to be quite evident south of Feysville, apparently consider this their most important piece of evidence, and is the only evidence stated in their report. Now the mapping of the district shows that shearing and foliation is very widely represented and generally runs north-north-west and south-south-east, and hence might easily be confused with the shearing caused in a north-west and south-east fault plane.

Further, Drs. Maclaren and Thomson, referring to the sedimentary beds, state:—

Between Kalgoorlie and Coolgardie the sedimentary beds are eleven miles broad across their strike; they run north-north-west across the low ground of the Kurrawang lakes and pass some distance west of Black Flag. To the south they are lost in the low lake country, and do not appear to pass beyond the Great Mt. Monger Fault Plane.

Subsequent mapping of the sedimentary beds has shown that they do extend for many miles south of the supposed Great Mt. Monger Fault Plane. The supposition that the sediments did not extend beyond the strike line of the fault plane has apparently weighed with Drs. Maclaren and Thomson in deciding the existence of that fault plane.

A study of the physiography of the area does, however, point to the existence of a fault plane, but striking almost across the direction of Drs. Maclaren and Thomson's Mt. Monger Fault Plane, viz.: east-north-east. The promontaries of the escarpment along the north shore of the Kurrawang lakes, if joined, form a line which, if produced, passes through a break in the ridges west of Kalgoorlie and through Lakeside, which is at the northern extremity of Hannan's Lake. A significant fact which strongly supports the existence of a fault, is that the sedimentary beds of the Kurrawang syncline occupy a less width south of the escarpment than they do north of it. The strike of this fault line is also parallel with the outcrops of a norite dyke passing through Wongi and Location 50, showing it coinciding in direction with a natural line of weakness along which, in the latter case, the newer basic dyke has intruded. This fault, if continuous for any distance, is of great economical importance owing to its probable effect on the southern continuation of the ore-bearing rocks of Kalgoorlie. From a study of the topography which is sketched on the accompanying map (Plate I.) it seems to pass north of Mt. Hunt and through Lakeside just above Hannan's Lake. There is no outcrop visible at the actual fault plane, but such outcrop may be found on further detailed mapping. From the fact, however, that the lakes occur on the south of the fault line, it may be supposed that that side represents more easily decomposed country, a condition of affairs which would most likely be brought about by a south dipping fault, because of the acute angled wedge of rock exposed to weathering (*see* Fig. 6).

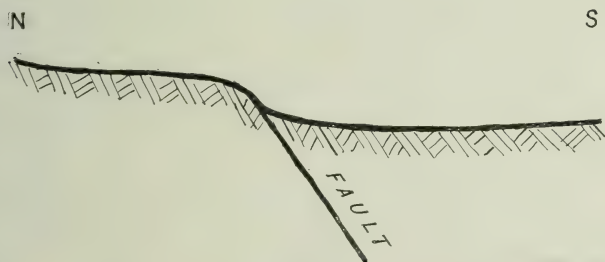


FIG 6.

Diagrammatic section of the Kurrawang Fault.

Since the Kurrawang syncline series is narrower south of the escarpment, the fault is a reversed or overthrust fault.

Further evidence will be required to substantiate the persistency of this fault line eastwards, and its extension in that direction would have an important bearing on the economic geology of the Kalgoorlie Goldfield.

Drs. Maclaren and Thomson, referring to "several series of overthrust faults," the existence of which my observations have confirmed and are referred to by me as reversed faults, say:—

The most important series has an east and west strike, and the position of the various members of this series is best indicated by the irregularity of the contact of granite and greenstone near Coolgardie.

Subsequent mapping does not confirm the existence of an east and west series, though a series striking east-north-east at right angles to the general strike of the country does exist; but the contact of granite and greenstone rather indicates faults, if any, in a north and south direction, as is shown by Mr. Torrington Blatchford's mapping at Coolgardie.*

CONCLUSIONS.—Summarising the results of my observations in the field, and of Mr. Farquharson's examination of thin sections of specimens collected, in conjunction with the results from the northern area as set out in Bulletin No. 56, the following conclusions have been arrived at:—

(1.) On reconsideration, with further evidence to dispose of, the rocks of the district, apart from the recent superficial deposits, are now divided into two series, unconformable with each other, viz.:—

- (a) Kurrawang Series;
- (b) Kalgoorlie Series.

(2.) Judging by the writings of American Geologists there appears to be a striking lithological and structural resemblance of the Kalgoorlie series to the Huronian series as developed in the Lake Superior district of America; and of the Kurrawang series to the Keeweenawan series which rests unconformably on the Huronian rocks of Lake Superior. Both are of Pre-Cambrian age, which is the age assigned to the Kalgoorlie rocks both by Mr. Gibb Maitland and by Mr. Gibson.

(3.) The Kalgoorlie series consists of highly metamorphosed acid and basic volcanic flows and sills, with breccias, agglomerates and sediments in subordinate amount.

(4.) Amphibolisation and carbonation of the Kalgoorlie series by regional and local metamorphism.

(5.) The Kurrawang series is a crushed syncline of sedimentary rocks.

(6.) The intrusion of the Kalgoorlie series by gabbros and porphyries, some of which may have been originated by extreme metamorphism from volcanic rocks. In some cases their apparent derivation from bedded rocks is shown by the presence of agglomerates in them (*see* Bulletin No. 56, p. 18).

(7.) The intrusion of granite with contact metamorphism of the intruded rocks. The metamorphic effect of the granite extends in some cases for over a mile from the contact.

(8.) The whole country has been foliated, sheared, and faulted by a series of separate and distinct earth movements, with the result that the foliation strikes north-north-west with shear zones in a parallel direction and faulting along and across the direction of shearing. Some of the fissures and shear zones have since been filled and impregnated with quartz and other minerals, resulting in the formation of auriferous lodes and reefs.

VI.—MINING GEOLOGY.

GOLDEN RIDGE.—A geological map of the Golden Ridge Gold Mining Company's properties and some adjoining abandoned leases, covering $1\frac{1}{2}$ square miles, with the Golden Ridge Mine as a centre, has been prepared and shows the principal geological features (Plate III.). The surface outcrops in this particular locality are more than ordinarily altered by weathering due to the circulation of meteoric waters, resulting in oxidation to a considerable depth and a re-distribution of the weathered constituents near the surface, as is shown by the formation of laterites, iron caps, and the silification of the outcrops of certain schists and banded rocks. Besides this, the actual outcrops of bed rock are scarce east of the main shaft, and practically non-existent westwards. Hence the impossibility of making an accurate geological map from surface indications alone. Fortunately the underground workings of the mine expose to view sufficient of the ore-bearing country and the adjoining rocks for purposes of accurate geological mapping.

History.—The first record of any serious work being done in this district was in 1897 when the Golden Ridge Proprietary, Ltd. commenced operations at Boorara, $3\frac{1}{2}$ miles north-north-west of where the present company is conducting operations. The mine was prospected in the first instance by John and James Prior, who sold it to an English company. The latter did not put up any treatment plant, but merely paddocked their ore. About this time (1897), a Kalgoorlie syndicate, the Golden Ridge Proprietary, Ltd., from which originated the present Golden Ridge Mining Company, stepped in and, according to report, bought the mine for £500. Their first crushing, which was taken to Kalgoorlie for treatment, is said to have yielded over an ounce to the ton. The first recorded crushing in 1897 was 127 tons for 234 ozs. of gold. Later on some Italian woodcutters discovered the Waterfall, $3\frac{1}{2}$ miles south-south-east of Boorara, which is not noted for an abundance of flowing water as its name suggests, but is said to have derived the name from an accidental falling of a water bag from a sapling growing near the reef.

Then the Golden Ridge Gold Mining Company bought the Waterfall mine from the prospectors and built a tramline connecting it with their battery at Boorara. Subsequently the Boorara leases were abandoned and a new plant erected at Waterfall, where the Company has continued its operations up to the present day.

The following is a record of the gold yield from Boorara and Waterfall from 1897 to 1913, kindly supplied by the Statistical Branch of the Mines Department:—

Period.	Dollied and Speci- mens.	Ore Treated.	Gold therefrom.	Total.
	ozs.	tons. (2,240lbs.)	ozs.	ozs.
Golden Ridge, W.A., Pro- prietary, Ltd.—				
Prior to 1897	..	·08	·47	·47
1897	..	127·50	234·07	234·07
1898	..	139·20	254·74	254·74
1899	..	56·00	63·50	63·50
Golden Ridge Proprietary Leases—				
1900	13·85	321·00	346·68	360·53
1901	..	1,023·00	805·07	805·07
1902	35·85	779·00	399·51	435·36
1903	..	4,351·00	5,071·60	5,071·60
1904	..	14,303·00	9,783·98	9,783·98
1905	..	24,649·00	9,959·20	9,959·20
1906	..	983·00	3,705·19	3,705·19
Waterfall Leases—				
1901	..	160·00	228·06	228·06
1902	..	1,867·00	1,043·68	1,043·68
1903	..	822·00	1,117·74	1,117·74
Golden Ridge G.M. Co., Ltd.—				
1906	..	4,203·00	2,192·71	2,192·71
1907	..	14,035·00	9,089·91	9,089·91
1908	..	22,583·00	14,424·45	14,424·45
1909	..	24,133·75	16,126·59	16,126·59
1910	..	25,801·00	18,021·37	18,021·37
1911	..	29,387·00	17,496·80	17,496·80
1912*	..	31,457·00	14,718·50	14,718·50
1913	..	30,303·00	13,063·33	13,063·33
Total ..	49·70	239,482·53	138,147·15	138,196·58

* Silver, 308·79ozs.

Topography.—The Golden Ridge Gold Mine is situated on the western slope of an irregular ridge of hills trending in a north-north-westerly direction through Boorara, and intersecting the Bulong road at about 7 miles out from Kalgoorlie.

Near the Waterfall townsite the highest point of this ridge is represented by a bold hill situated 56 chains north-east of the main shaft of the Golden Ridge Mine. The western slope is steep for 20 chains from the summit, and gradually loses gradient near the mine, from which place the country slopes very gradually westwards terminating in the sand plain that skirts the south-eastern shore of Hannan's Lake. The rock in which the auriferous reefs of the mine occur is not characterised by any topographical feature, and on the surface alone it would be very difficult to define its boundaries. The adjoining schists and quartzites are marked by the crests of the numerous low hills which flank the immediate foot of the ridge. The manager's house is situated on a rise capped by an outcrop of quartzites and ferruginous schists, which follow the western boundary of the porphyry.

A rough contour sketch of the surface is shown on the accompanying geological map (Plate III.).

Geology.—The rocks of Golden Ridge, excluding the superficial deposits, may be divided into four main varieties:

- (1.) Quartz-porphyry;
- (2.) Chloritic quartz-porphyry;
- (3.) Tale-chlorite schist;
- (4.) Graphitic slate.

The Quartz-porphyry is the most important rock because the auriferous reefs worked by the Golden Ridge Gold Mining Company are solely confined within its boundaries. It [13520] is a pale olive green rock of medium texture and a rather felsitic appearance, but with a decidedly porphyritic structure, and containing blebs of quartz. From an examination of hand specimens it may be therefore classed as a quartz-porphyry, which is confirmed by petrological examination. The rock takes the form of a wide vertical bed or dyke with a strike of 340° , which coincides with the prevailing strike of the rocks of the Eastern Goldfields, and is bounded on the west by quartzites and graphitic slates, and on the east by tale-chlorite schist. To the south the quartz-porphyry apparently thins out, being greatly reduced in width as is shown at the 200ft. level of a shaft in the south-east corner of G.M.L. 3294E, the total width being here a little over 200 feet, while in the north block opposite No. 2 east shaft, the width is 400 feet. This shows that the walls of the quartz-porphyry converge towards the south. That it actually dies out beyond the south shaft it is impossible to say, owing to the covering on the surface, and the difficulty of recognising any surface outcrop. There is, however, strong evidence of its dying out southwards. As regards the origin of this mass of quartz-porphyry, it is

hard to say definitely how it was formed, but it is my opinion that it is not a true dyke, for the following reasons:—

- (a) There are no signs of intrusive arms from the main body into either the schists or slates;
- (b) No signs of typical contact metamorphism;
- (c) The great length of the porphyry is conformable with the strike of the adjoining schists;
- (d) There are also no ruptures in the schists or slates as would be caused by a dyke 300 feet wide intruding into them;
- (e) The talc-chlorite schist and the graphitic slates are exclusively confined to separate sides of the porphyry, and portions of neither walls are included in the latter.

My opinion, therefore, is that the porphyry is conformable with the adjoining schists, quartzites, breccias, and greenstones, and is part of the same series but, owing to a difference in its composition, it is less amenable to the production of schistosity where subjected to lateral pressure, with the result that fracturing and brecciation took place instead. The fracturing has been accompanied by faulting and the formation of spaces of discission which have become filled with quartz and associated minerals resulting in the formation of quartz reefs. It is probable that this rock was originally a volcanic sill, or lava-flow conformable with the graphitic slates and greenstones. The boundaries on the eastern side are not as distinct as on the western, though in places they are very sharp.

The graphitic slates are in my opinion of sedimentary origin, and are associated with breccias of volcanic appearance, which can be seen in a decomposed state on the dump of a shaft in the north-east corner of G.M.L. 3924E.

In the porphyry mass itself a number of interesting brecciated zones occur; one on the western margin, another at the centre near No. 2 shaft in the north block, and a third at the southern end of the east cross-cut from the shaft in the south block. The presence of these brecciated zones is not easy to account for. They certainly have the appearance of crush-breccias, the composite fragments being all of a similar nature, and if the margins of the fragments could be obliterated, the rock would be a homogeneous mass of porphyry. On the other hand, if this rock was originally a volcanic bed conformable with the neighbouring schists, it is quite possible that it originally contained bands of volcanic porphyry breccia which have since been crushed and metamorphosed to such an extent that they have lost their original structure.

Oxidation in the porphyry, as in the adjoining schists, has gone on to considerable depths. There is a gradual change from oxidised

to sulphide country between the 200 feet and 300 feet levels. There are two distinct periods of fracturing in this rock:—

- (a) Resulting in the formation of fractures or spaces of dissection in the porphyry, and subsequent filling with quartz; and
- (b) Later in the formation of a system of faulting extending through the whole series, greenstone and schists included.

The first movement is confined to the porphyry and is, in my opinion, contemporaneous with the formation of the schistose structure in the neighbouring rocks. An interesting variation in the porphyry country is the change of the country from pale olive green to dark green due to the presence of chlorite in the latter. These variations from quartz-porphry to chloritic-quartz-porphry cannot be accurately mapped as their boundaries are not sufficiently exposed by the underground workings. The variation may have some bearing on the deposition of the quartz reefs, and it is possible that the chloritic green areas (which show a slight incipient schistosity) represent country in which the reefs will be found to be less defined. This is borne out by the fact that the productive reefs are confined to the non-chloritic porphyry.

It is highly probable that the quartz porphyry is a bleached chloritic quartz-porphry. This is supported by the fact that in proximity to the lodes in the Golden Mile the country rock has been bleached in the same way by the elimination of chlorite.

The chloritic-quartz-porphry occurs west again of the graphitic slate and according to the petrologist is exactly similar to the chloritic porphyry associated with the ore-bearing quartz-porphry. This indicates that the bleached porphyry is the productive zone of the mine and that any prospecting work to the west that does not reveal the bleached rock is unlikely to be attended with success. It may be added that there is no defined contact between the quartz-porphry and the chloritic porphyry, but a gradual mergence of one into the other, which is also characteristic of the bleached and unbleached rock on the Golden Mile.

On the east of the porphyry country there is a wide belt of greenstone with strong schistosity developed. At the contact with the porphyry it is a talc-chlorite-schist. Further east the greenstone has apparently interbedded with it banded quartzites and more obviously schistose bands which weather less rapidly than the greenstones, and leave ironstone-capped ridges and lines of hills. The quartzites can be followed along the same strike of 340° for over a mile.

Quartzites adjoin the western margin of the porphyry on the surface, but are represented by graphitic slates at depth. The quartzite is apparently only a surface alteration of the graphitic slates, which are of considerable width at the 400 feet level, being

there 40 feet thick. These schists have a very distinct banded structure, and have all the characteristics of sedimentary beds, being distinctly slaty in places and composed of alternating bands of fine and coarse grain. An interesting fact is the highly pyritiferous nature of these graphites. As far as 35 feet from the contact they contain abundance of pyrites, and close to the contact there are bands of almost solid pyrites. In view of the fact that occurrences of pyritiferous graphitic schists are associated with most of the important lode formations of the Kalgoorlie Goldfield, and that, in other gold-fields, ore bodies become considerably enriched in the neighbourhood of certain pyritiferous and carbonaceous bands of slate, *e.g.*, at Ballarat, Victoria, and Gympie, Queensland, it is more than likely that either the pyrites or the graphite, or both, on this mine were influential in causing the deposition of gold in the reefs of the adjoining porphyry.

As discovered from the results of boring, the graphitic slates are narrower at 600 feet, being only 15 feet in width. It is, however, worth noting that between the 500 and 570 feet levels the No. 2 Cross Reef follows the hanging wall of the contact and that in so doing, it gives the schists at this point a much gentler dip than generally at the contact. This points to the reef occupying the space of an ancient fault plane which has displaced the graphite to the west; and as soon as the footwall of the reef changes to schist, the reef should die out and the contact below this will probably regain its normal dip with a corresponding widening of the graphite again. The presence of prominent and extensive planes of slickensiding in the hanging wall of the reef, below the 500 feet level, supports this idea, which is illustrated in the following diagram (Fig. 7.)

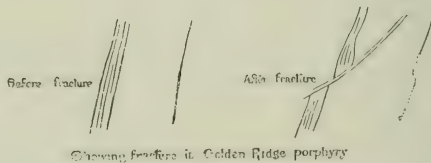


FIG. 7.

These sketches are based on a cross-section plotted at the point at which No. 2 Cross Reef comes in contact with the schist.

Along the western margin of the porphyry a number of prospecting shafts have been sunk, and are located on the accompanying geological map (Plate III.). On the dump of one of these there can be seen broken lumps of a very decomposed volcanic breccia which is distinctly different from the crush-breccia in the porphyry.

The graphitic slate on this dump is conspicuous by its absence, and it may be inferred that it pinches out at about opposite the south-west peg of the main lease, since there are no surface indications of it south of that point. The dump just referred to is in the north-east corner of G.M.L. 3924E, and appears to be mainly composed of decomposed greenstone schist and schistose volcanic breccia. In the southern leases no trace of the quartzite capping to the graphitic slate is noticeable, although schists of sedimentary appearance are in evidence; whereas northwards the quartzites which represent graphite on the surface can be traced along the contact, and show strongly as far as the porphyry itself.

The general geology may thus be summed up as follows:—

The Golden Ridge locality is composed of a very ancient, tilted, and crushed series of volcanic rocks, consisting of alternations of greenstones, slates, volcanic breccias, and porphyry. The crushing has resulted in the production of greenstone schists, and in the case of the harder and more tenacious porphyry in fracturing and faulting instead of foliation. The fissures thus formed, being the only channels for the circulation of ascending solutions, have now become filled with quartz and minerals distinctly crustified in places, and the deposition of the gold has probably been effected by the presence of graphite. Subsequently, weathering and oxidation near the surface, due to circulation of meteoric waters, has resulted in the deposition of secondary minerals and a concentration of gold at between 200 and 300 feet from the surface.

Economic Geology.—An analysis of the geological history of the rocks, as attempted above, points to a definite arrangement of quartz reefs depending on the nature of the fracturing resulting from the compressive force to which the porphyry has been subjected. The best way to understand the relations of the reefs is by a study of the laws of fracture by compression, which are to be found set out in any text book on the strength of materials. In experiments made on blocks of sandstone by subjecting them to compression until rupture takes place, it has been proved that generally two systems of fracture occur which have a strike roughly parallel on one surface and on surfaces perpendicular to it they cross each other approximately at right angles. They thus form what are known as subjugated fractures. These fractures generally make an angle of 35° with the direction of the compression force under the experimental conditions which do not coincide exactly with those actually obtaining in a rock mass. The actual conditions, which are those of a narrow vertical band of rock enclosed on three sides and open at the surface, would result in a modification of the angle of rupture obtained under the experimental conditions.

Daubrée's experiments show that horizontal pressure results in subjugated fissures inclined at 45° to the line of pressure, and the

accompanying dislocations are largely reversed faults.* This investigator's experiments were carried out as nearly approximating natural conditions as is artificially possible.†

Fig. 8 is copied from Johnson's "Materials of Construction," and shows the results of compression on blocks of sandstone. This illustration shows a striking resemblance to the system of fractures in the Golden Ridge Mine, now represented by the quartz reefs in the porphyry. The similarity is particularly noticeable at the inter-

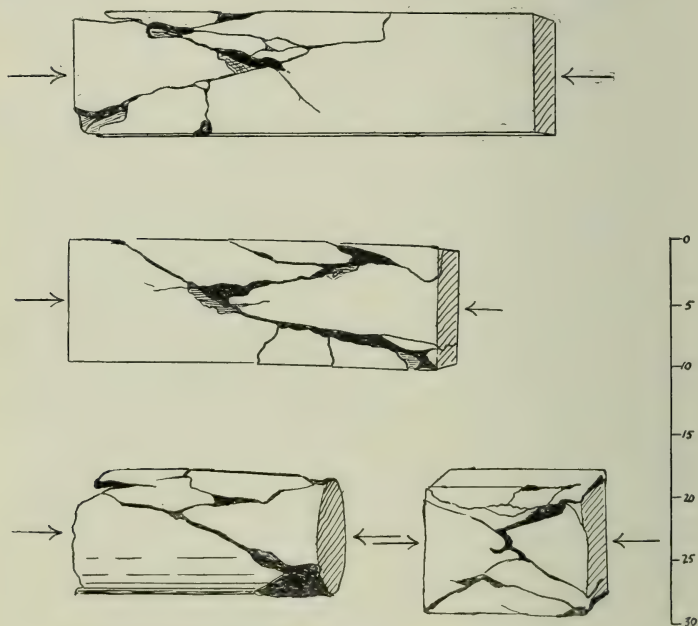


FIG. 8.
Compression tests on sandstone.

sections of fractures which have an exactly similar form to the intersections of the reefs. At the intersections the reefs become irregular and contain large masses of country as would be expected should such fractured openings become filled with quartz.

Besides the two conjugated fractures it is clear from the diagrams in Fig. 8 that other subsidiary features are liable to take place, and such are represented by the spur and footwall reefs in the Golden Ridge porphyry.

Supposing, therefore, that the reefs in the porphyry of the Golden Ridge Gold Mine represent planes of fracture, it is clear that there are three very distinct sets of these planes, represented:

(1) by the east and west reefs;

* Lindgren's Mineral Deposits, pp. 136-139.

† Etudes Synthétiques de Géologie Expérimentale, Paris, 1879.

- (2) by the cross reefs; and
- (3) by a long gently-dipping reef hitherto included as a part of No. 2 cross reef, but really representing a distinct plane of fracture which, for the purposes of this report, shall be called the "Main" reef.

Besides these three main planes or three series of parallel planes, there are minor representatives such as the footwall reef, branch veins and a gently-inclined reef now being developed at the 500 feet level, which latter reef dips at 15° to the north and strikes east and west.

Description of Reefs.—The reefs are all continuous sheets of quartz, but not of uniform thickness. They change in width at fre-

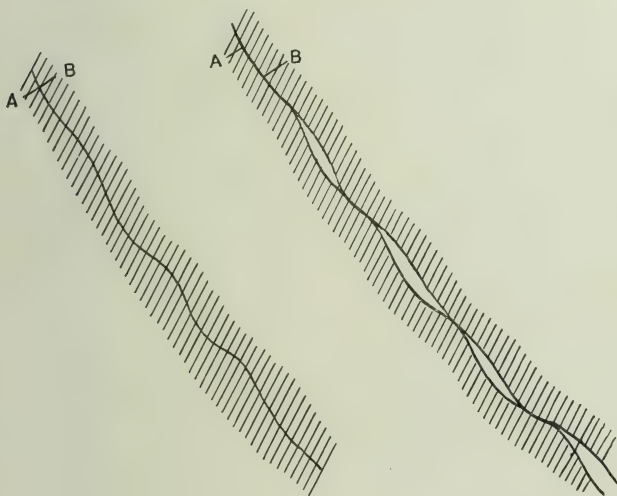


FIG. 9.
Fissures formed along a fault plane.

quent intervals from broad bodies of stone to thin veins, thus virtually forming a series of connected lenses. This would be caused by dislocation along an irregular fracture, which is usually illustrated as in Fig. 9.

Such dislocation is proved by the presence of slickensided walls on the reefs. The reversed character of the faulting is not clear from the disposition of the reefs themselves, but from the reef at the 570 feet level, as sketched in Fig. 7, reversed faulting has apparently taken place.

The reef is up to five feet wide in places, and narrows down to a few inches or a thread. The boundaries of the reefs are for the most part sharp and distinct, but a series of veinlets, generally parallel

with the walls of the reef, traverse the adjoining country for some distance from the reef; sometimes the veinlets are in the form of irregular branched stringers, and run for considerable distances from the reef. The junctions of the reefs are not observable in many places in the mine, but it seems to be generally the case that the



FIG. 10.

Photo., R. H. Irwin.

[13569]—From Golden Ridge No. 2 Cross Reef, 465ft. Level.

Neg. 1317.

country is more disturbed at the junction, and the ore body irregular in form. In some places, where three separate reefs intersect, there is a great jumble of quartz, and it is almost impossible to differentiate the separate reefs.

Mineralisation of the Reefs.—The reefs show a distinctly crus-tified structure in places (see Fig. 10), but are generally composed

of white milky quartz with central druses penetrated by quartz crystals. In places there are crusts of calcite in the quartz and irregular patches of galena and zinc blende arranged in line towards the centre of the reef. The pyrites generally occupies the margins and the adjoining country rock (Fig. 10). The presence of galena is considered a good indication for gold, as where there is an absence of this mineral the gold values are low, and the reef not profitable.

In the cross-reefs there are large portions of reef composed of a clear white quartz of good average width, but not rich enough to pay to take out. The "Main Reef" has been fairly well stoped down to the 500ft. level. It is interesting to note that gold also occurs in the small veinlets adjoining the reefs, but not in payable quantities.

Ore Genesis.—The lateral pressure to which the body of chloritic quartz-porphyry and its neighbouring volcanic rocks have been subjected, has resulted in the formation of a zone of fracturing in which large intersecting fault planes have been formed.

Movement in these fault planes has caused the formation of open spaces and numerous fissures in the rock accompanied by leaching of that part of the porphyry in which the main fracture have taken place. Circulating solutions from a deep source have found these passages and circulated freely through them, completely filling them with quartz.

As the deposition of the quartz was proceeding from the walls towards the centre, the following combination of conditions was probably present, which would be favourable to the deposition of gold and other minerals:—

- (a) High temperatures and pressures of the solutions decreasing as the solutions ascend the fissures;
- (b) The narrowing of the channel by the continual deposition of the quartz;
- (c) The meeting of different solutions at the intersection of fissures;
- (d) Emanation of hydrocarbons from the graphitic slates which might cause the deposition of gold;
- (e) Constrictions where walls of fissures are in contact; and
- (f) Reaction of the solutions with the country rock resulting in the bleaching of the latter by the removal of chlorite and a corresponding deposition of other minerals, *e.g.*, pyrites.

In the mine it is very noticeable that where the reef is large and persistent, with clean walls undisturbed by minor fissuring, the gold content is lowest. The reefs and their walls are most disturbed at intersections, and according to mine sections the reef has been most profitable at and close to these intersections.

The faulting of the reefs, which is post-mineral, has had no influence on the deposition of gold in the reefs, except perhaps later on by influencing secondary enrichment by providing channels for the circulation of the surface waters.

Following the formation of the auriferous reefs, denudation and weathering of the rocks by surface waters has resulted in secondary enrichment on the cap of the sulphide zone which, at Golden Ridge is situated between the 200ft. and 300ft. levels, and according to figures supplied by the manager the richest ore was obtained from between these two levels.

Future Prospects and Recommendations.—As regards the future prospects of this mine the following questions present themselves:—

- (1) Will the porphyry live in depth?
- (2) If so, will the quartz reefs live in the porphyry?
- (3) Will the quartz reefs live in the schists?
- (4) Are the reefs likely to be auriferous at depth?
- (5) What is the quickest and cheapest way to open up new ore bodies?

The answer to the first question is "Yes," for the following reasons:—

(a) The porphyry shows no signs of narrowing at the lowest level.

(b) The porphyry can be traced on the surface for three-quarters of a mile or nearly 4,000 feet, and is probably much longer; so that it is almost certain to extend to at least 2,000 feet in depth and it is my opinion that it will be found to extend to a much greater depth.

(2.) Will the quartz reefs live in the porphyry? If these reefs represent spaces of discission formed by a regional pressure exerted at right angles to the strike of the porphyry, the whole of the mass must have been affected in the same way, and it is therefore probable that fissures are distributed fairly regularly throughout it, and consequently the quartz reefs which now fill these fissures can be reasonably expected to live in the porphyry, and to be repeated in a similar manner to which they occur in the levels already worked both in depth and longitudinally.

(3.) Will the quartz reefs live in the schists? The answer is "No," because from the past experience in working the mine, in not a single instance has a reef been known to live beyond the contact zone. At the eastern contact the reef is good and strong right up to a point where there is a zone of country in which the reef breaks up into a number of leaders and stringers of quartz which gradually die out in the adjoining greenstone schist. The schistose rock is apparently not favourable to the formation of fissures or open spaces which, in the porphyry owing to greater elasticity, are readily produced and preserved.

(4.) Are the reefs likely to be auriferous at depth? It is reported that on this mine the richest ore was taken out at the 300ft. level, which is just below the oxidised zone. But a reef carrying fair values has been found at the lowest level in the mine, viz., 570 feet, which is 300 feet below the oxidised zone and should be well out of any zone of surface enrichment. Within 13 miles of the mine profitable ore is being worked at 2,500 feet below the surface on the Golden Mile, but from lode formations. However, gold has also been won at great depth from crustified quartz reefs, *e.g.*, Cohen's Reef, Walhalla, worked to over 3,000 feet, and saddle reefs, Bendigo, over 4,000 feet, although the conditions under which Cohen's Reef and the Bendigo reefs occur differ greatly from those in Western Australia. So there should be every prospect of an extension of the auriferous character of the reefs at depth. But whether of payable quality is another question which depends on two factors:—

- (a) Increased cost of mining at depth.
- (b) Decrease in value of the reefs generally below the 300ft. level, as shown by figures supplied by the manager. These figures show that in all the reefs worked the most valuable ore has been taken from between the 200ft. and 300ft. levels. It is therefore evident that the chances of the reefs at depth being the payable propositions they were in the upper levels are small. Both their scattered distribution and narrow width preclude them from being worked as low-grade ore. Rich patches would probably be found at depth, but the average value of the reefs would not come up to that of the ore that has been taken out of the upper levels.

(5.) What is the quickest and cheapest way to open up new ore bodies? From the above remarks it follows that there are sound reasons in favour of (a) the porphyry extending for some considerable depth, (b) reefs of similar nature and distribution to those at present worked, being found in the lower portions of the porphyry just as they do exist longitudinally in the north block, (c) the reefs if found at depth being auriferous, but mining alone can prove whether they will be profitable or not.

There are four directions in which prospecting is justifiable:—

(i.) For the extension of the "Main Reef" west of its intersection with No. 2 cross reef.

(ii.) For new reefs in the lower levels of the eastern portion of the porphyry, where there are possibilities of discovering three kinds of reefs, viz.:—

- (a) Parallel to and below "Main Reef."
- (b) Parallel to and below cross reefs.
- (c) Parallel to and below west reef or footwall reef.

(iii.) In the north block.

(iv.) For the extension of the "Main Reef" below 500ft. level.

The first would be prospected by driving past the intersections with No. 2 cross reef on 200ft., 300ft., and 500ft. levels. The intersection not being so plain on the 400ft. level should be left to the last. Or, by boring upwards from one of the levels along No. 2 cross reef south of its intersection with the "Main Reef," in a direction at right angles to the plane of the main reef. At least three bores would be necessary from one level, the best being the 300ft. level where the ground will be easier to bore than in the lower levels.

(ii.) The second direction, by a series of bores from say the drive on No. 2 cross reef on 400ft. level at right angles to the probable plane of the reefs. Say three upwards and three downwards from the same level. The former to intersect easterly dipping reefs and the latter westerly dipping reefs. If the cost of cross-cutting and driving is not appreciably greater than the cost of a system of bores as proposed above, it would be infinitely more satisfactory provided a fair length of driving could be undertaken.

(iii.) The third in the north block, by sinking on the reefs already opened up, and keeping a look-out for enrichment where the country changes from oxidised to sulphide zone. The deepest workings have not yet penetrated the sulphide country, and I should think it worth while to sink on the most promising of the quartz reefs until sulphide country is penetrated.

(iv.) The fourth by sinking a winze on the reef or sinking the main shaft or cross-cutting under the "Main Reef." A winze had already been started from the 500ft. level, but the flow of water was too great and the winze had to be abandoned.

In conclusion, I would recommend exploration of the upper levels, in the first three directions suggested above in numerical order, and it is hardly necessary for me to advise caution before sinking to exploit the mine at depth.

The above remarks are based on conclusions logically deduced from a geological examination of the mine and the surrounding country in conjunction with a study of figures supplied of the values of the ore already taken out of the mine, and are not offered to supersede the lines on which the present development of the mine is being undertaken, but are put forward in the hope that they may be of some assistance to the management in formulating a scheme for prospecting the undeveloped portions of the mine.

BOORARA.—All mining at the Boorara Centre, except for a little desultory prospecting, has now ceased. It is situated eleven miles by surveyed road in an east-north-easterly direction from Kalgoorlie.

It was here that the Golden Ridge Proprietary Company was operating before it took over the Waterfall leases, which are situated $3\frac{1}{2}$ miles further southwards.

The old Golden Ridge Proprietary Mine has been shut down for a number of years, and most of the underground workings are therefore inaccessible. The ladder-way in the main shaft was in good condition as far as the water level at about 230 feet. The workings at the 100ft. level were quite unsafe owing to the decomposed nature of the ground. But the 200ft. level, being in harder and less weathered country, was safe, and a sketch plan of the same drawn to scale is attached (Fig. 11).

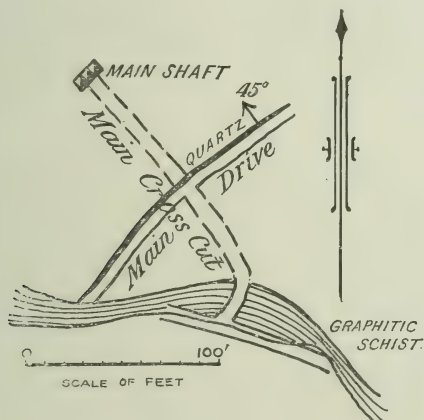


FIG. 11.

Sketch plan of No. 2 Level of old Boorara Workings, Golden Ridge G.M. Co.

All the other shafts in the vicinity, except on Higgins and party's lease, were inaccessible.

In 1903 Mr. A. Montgomery, the State Mining Engineer, visited this locality when the underground workings were accessible. His report, which gives the best account of the now hidden workings, reads as follows:—

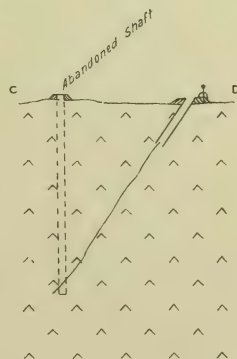
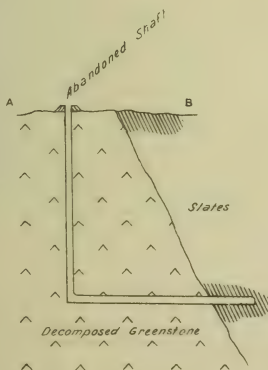
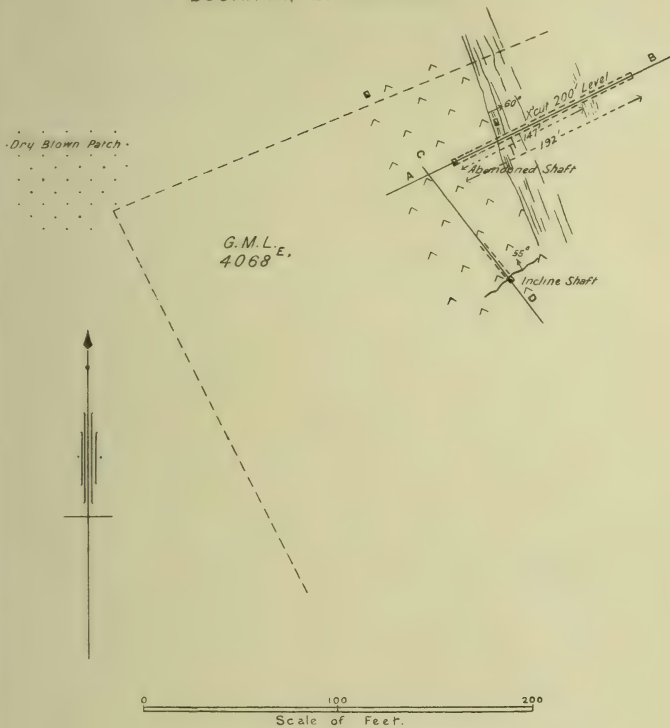
In the Golden Ridge Mine there are two lode "formations" running north-westerly with a cross lode underlaying about one in one running between them. The more westerly lode shows on the surface as a big outcrop of somewhat laminated jasper and ironstone, and the eastern lode is a large badly defined body of soft whitish kaolin traversed by quartz veins. In a prospecting shaft, 40ft. deep, on this a quantity of the lode matter has been extracted, 100 tons having been said to have returned 10 dwts. to the ton when crushed at Kalgoorlie, and 40 tons 5 dwts. to the ton when treated at Boorara. This soft lode is considered to be a low-grade ore body which might be treated, if there were plenty of water available. On account of its clayey character it requires a large amount of water when being crushed. At the 100ft. level from the main shaft this lode is still a soft decomposed clayey ore body of low

grade, and the western lode is here also a big soft clayey body, unlike the ironstone forming its cap at the surface. At the 200ft. level the principal workings are on the cross vein, which is a cross lode one to three feet thick underlying to the south-east about one in one. This has yielded very payable stone, which has enabled the owners to put up a battery, and still further open the mine. The water level is 250 feet in the main shaft, but there was not much water in the mine when I visited it, about 5,000 gallons a day, or barely enough for the battery of 10 heads of stamps. At the 300 feet level the cross lode continued to give good stone, and contained a great deal of arsenical pyrites. The main shaft is sunk vertically to 400 feet, but when I visited the mine the lowest level was at 360 feet, where a cross-cut was being driven out to intersect the lode. On account of its flat underlay the lode is getting further and further away from the shaft as the latter is sunk, and an inclined shaft will probably have to be considered before very long. The cross lode seems to terminate against the mullocky lodes lying east and west of it, but may possibly be faulted by these. I am, however, inclined to think that it is a result of side pressure fracturing the block of ground between these two, as has been above put forward in the case of the Mt. Bellow Mine at Ballagundi. The country in depth is seen to be a greenstone schist, but near the surface, this is much weathered and softened Since the arsenical pyrites has come in at the lower levels, the battery has had to concentrate these after crushing, the concentrates being shipped to Dapto for treatment.

No other mines of any importance have been worked in this locality. A good deal of prospecting has been done to the north as far as and beyond the Bulong road. These leases were known as the Corsair Group, and no serious work has been done on any of them. A prominent quartz formation striking in a north-north-westerly direction outcrops for a considerable distance passing just west of Boorara Townsite and cutting the Kalgoorlie road about five chains south-east of the south-west peg of G.M.L. 2367E. This reef culminates to the north in a prominent landmark known locally as "The Blow" about two miles north-north-west of Boorara. On the western foot of "The Blow," which is a huge "buck" reef, a good deal of surface prospecting and dry-blowing has been done. This reef has also been worked at its southern visible extremity on the Grace Darling Lease, G.M.L. 3949E. There are no official records of gold won from or in the vicinity of the reef. It is possible, however, that the dry-blown patch west of "The Blow" represents alluvial containing gold shed from the hanging wall of the reef or some parallel lode. At the Grace Darling the reef itself has been worked, but it is only a few feet in width.

South of the old Golden Ridge Mine (about a quarter of a mile), an abandoned lease was being worked by Higgins and party for a Kalgoorlie syndicate. They started work on some old workings at the head of an old alluvial patch and got 40 ozs. out of a load of ore. This was in a narrow quartz formation associated with a band of ironstone. The gold occurred close to the ironstone and in the form of a short shoot. After working out this shoot of gold, this party transferred its operations to further up the hill, there working on a narrow quartz reef in decomposed greenstone country. The reef carried gold but was not payable. In places it split into a series

PLAN & SECTIONS
OF
HIGGINS & PARTY'S WORKINGS.
BOORARA, E. COOLGARDIE C. F.



C.B. Kidson, del.

of parallel leaders having the appearance of a lode. In an abandoned shaft the same reef is seen cutting across the bottom of the shaft at 200 feet, and is driven on for 20 feet when it splits up into two thin veins which appear to run into the north wall of the drive. This drive is 192 feet long, and at 147 feet passes into graphitic slates dipping 60° to the east (*see* Fig. 12). The reef is parallel to and has the same dip as the cross reef in the 200ft. level of the old Golden Ridge Mine, and therefore probably occupies one of a series of fissures running across the same belt of greenstone and dipping about 55° to the north-north-west.

A reef having the same strike and dip can be seen half way between Boorara and Waterfall and about two chains west of the road.

Some good alluvial patches have been worked in the gullies around Boorara, and it is reported that nuggets up to 24ozs. weight have been found. Also, amongst others, 22ozs., 16ozs., and 8ozs.

The gold yield for this centre, exclusive of the Golden Ridge Gold Mining Company's, is 626ozs. from 1,905 tons of ore, which gives an average of 6.57dwts. per ton, or with dollied gold 8.9dwts. per ton.

The following is a table of the gold returns as recorded by Mines Department:—

BOORARA.

Year.	Name.	Dollied and Alluvial.	Ore Treated.	Gold therefrom.
1904	Waterfall Consols, G.M.L. 4060E	ozs. 9.73	tons. ..	ozs. ..
Previous to 1907	Crown Jewel, G.M.L. 4041E..	..	600.00	35.43
1907	Do. do. ..	..	130.00	4.45
	Golden Ridge, G.M.L. 4297E	..	120.00	6.29
	Reclaimed G.M.L. 4279E ..	1.50	..	..
	Do. 4289E ..	54.35	..	..
1908	Golden Ridge, G.M.L. 4297E	132.74	8.00	160.67
	Pearl, G.M.L. 4314E ..	..	45.00	9.12
	Reclaimed G.M.L. 4298E ..	20.26	..	..
1909	Golden Ridge Reclaimed G.M. Co., G.M.Ls. 4297E, 4298E	..	880.00	303.46
	Pearl, G.M.L. 4314E ..	..	37.50	11.31
	Sundry Claims ..	{ doll. 2.30 alluv. .49 }	{ 35.00 }	17.46
1910	Pearl, G.M.L. 4314E.. ..	..	35.35	2.40
	Sundry Claims	..	10.00	3.41
1913	Sundry Claims	..	4.00	72.41
		221.37	1,904.85	626.41
				221.37
	Total Gold	..	..	847.78

Average = 8.9dwts. per ton.

FEYSVILLE.—This centre includes Location 50 of the Hampton Properties, Ltd., on which most of the work in this locality has been done. At the time of this survey five parties were operating in the centre—

- (1) The Speakman Syndicate on the old Hampton Boulder Lease No. 15, Location 50;
- (2) Smith and party on the Little Wonder Lease No. 17;
- (3) Tributers Irvine, Johnson, and Sullivan on Battery Lease No. 1, Location 50;
- (4) O'Donnell and Cummings on Battery Lease No. 3, Location 50; and
- (5) Hassell and party on the old Michael Angelo Lode, G.M.L. 3746E, half a mile north of the north-west corner of the Feysville Townsite.

(1.) *The Speakman Syndicate*.—This syndicate is working close to the south boundary of Location 50 on the old Hampton Boulder Lease No. 15. There are no records of the work done by the old company, though apparently a considerable amount of money has been spent, as is testified by five large open-cuts, two in Location 50 and three in Location 48 on the same line of formation. A large wooden poppet-head has been erected over one shaft. The ore shoots, bins, and an old tramline for conveying ore to the Merry Hampton Battery in Location 48, are still in position.

As seen on the accompanying geological map of the Speakman Syndicate's properties (Plate IX.), the ore body is a large lenticular mass of quartz porphyry bounded by greenstone schists. On the east there are more parallel bands of the same type of porphyry. Its strike is about 335° , and on the west boundary of the lease another development of granitic porphyry occurs which has a strike of 305° , being inclined at 30° to the main ore body having a distinctly different appearance to the main mass, and probably of later origin. Close to the western wall of the main mass there is a considerable development of quartzitic schists and sheared porphyry which is undoubtedly older than the porphyry. There are, therefore, three distinct ages of porphyry:—

- (a) Sheared porphyry belonging to the greenstone schist series;
- (b) Felsitic porphyry (auriferous) and intrusive into the greenstone schist; and
- (c) A later intrusion of granitic porphyry.

The main felsitic porphyry mass has two bulges, giving it a greatest width of four chains, or roughly 250 feet. In Location 50 it has a length of over 30 chains, and in Location 48 it becomes narrowed down to 30 feet, and extends indefinitely to the south-east.

In Location 50 the dyke has been worked by open-cut. The northernmost cut is 60 feet by 120 feet and 50 feet deep, and is alongside the western contact. The south cut is a little smaller and also on the western contact.

In Location 48 there are three long open-cuts on the western contact.

For convenience of description these open-cuts are numbered on the map from north to south as 1, 2, 3, 4, and 5.

No. 1 *Open-cut* is in a fine-grained felsitic porphyry which is pink near the surface and greenish-white at depth. In this quarry it is evident that since intrusion the dyke has been subjected to two separate movements; firstly a lateral pressure resulting in two sets of shear planes dipping at a high angle in opposite directions; along these fissures ironstained seams occur in which the gold has been deposited. Secondly a later movement resulting in planes of parting, two sets being discernable, one horizontal and the other vertical, and across the strike. The gold-bearing seams have an average strike of 300° and are apparently confined to the steeply inclined shear planes. Gold can be seen with the naked eye in hand specimens, but it is always confined to the ironstained seams and tiny quartz veinlets. In no instance could gold be seen in the porphyry itself. The seams appear to be universally distributed throughout the dyke which accounts for values being found almost anywhere in the dyke, according to prospectors. There are, however, wide bands of massive and seamless porphyry between the seams which would carry very little, if any, gold. There are also places where the seams are more numerous and therefore where values would be higher. Trial crushings from this dyke have given from 6 to 10 dwts. per ton, but as these crushings would be taken from where the dish prospects could be obtained, they would come from where the seams occurred in the dyke. As all the work appears to have been done on the western wall of the dyke, it is most probable that the gold has been derived from the western contact with the schists.

The following is a diagrammatic sketch of the seams in the porphyry (see Fig. 13). It shows two sets of steeply inclined shear planes and two sets of planes of parting, one shown horizontally and the other occurring in the plane of the figure.

The shaft to the west of the open-cut has a large wooden poppet-head over it, but no ladder-way, and is inaccessible. The dumps show a carbonated chlorite schist impregnated with pyrites, apparently derived from an amphibolite schist by contact with the porphyry dyke. About 18,000 tons of stone must have been taken out of this open-cut. But no returns are available as to the results of treatment.

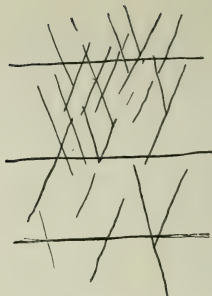


Fig. 13.

Shear and parting planes in porphyry on Speakman's Workings, Location 50.

No. 2 *Open-cut* is a little smaller than No. 1, and the stone exposed is identical. On the west a shaft has been sunk to 100 feet and a cross-cut put in on a bearing of 71° for 104 feet, showing porphyry for 95 feet of that distance. The contact is nine feet east of the shaft and a rise has been started at 42 feet from the shaft. Porphyry still shows in the end of the cross-cut and the contact is dipping to the west. A specimen of the contact work was collected and has been reported on by Mr. Farquharson as follows:—

[13580]. Bottom of No. 2 shaft, Hampton Boulder Lease.

A dark grey rock with lighter streaks, the dark patches containing much pyrites. A section consists almost wholly of more or less allotriomorphic plates—some rather stout columnar—of a clouded twinned plagioclase feldspar with plates, grains, and patches of calcite, and small flakes, strings, and flaky aggregates of a brown slightly pleochroic biotitic chlorite with frequent aggregate polarization. There are also prominent crystals of pyrites and of black iron ore—magnetite. Some flakes have the characters of biotite. There are needles of apatite and quartz grains associated with the calcite. The rock is apparently a junction phase of an acid dyke with a greenstone; the chloritic strings have been derived from the hornblende of the greenstone.

A contact rock of similar occurrence in connection with intrusive porphyry can be seen north of Feysville from dump of shaft on G.M.L. 3902E, and is described thus:—

[13541]. Rather similar to [13580]. It consists largely of large feldspar plates and plates and grains of calcite with much pale greenish chlorite in comminuted scales, stringy aggregates and irregular platy forms. The chlorite in this case is almost certainly derived from hornblende. Quartz is present in grains and larger plates, in places as a coarse mosaic. There is much pyrites. The rock is an altered feldspar-chlorite-calcite rock, probably derived from an amphibolite by feldspathisation due to an intrusive dyke. The species of feldspar was not ascertainable with certainty in the section, but an observation of the extinction angles in one section agreed sensibly with those of albite.

No. 3 Open-cut is six chains long by 30 feet wide and 30 feet deep. Here the porphyry dyke has divided into two arms enclosing greenstone schist. The contact between the eastern arm and the "horse" of greenstone schist appears to have been worked. Above the north end of the open-cut a shaft has been sunk in a talc-schist, and two chains north again of this shaft an inclined shaft has been put down underlying 20° to the south, apparently to undercut No. 3 open-cut. The dump from this incline shaft consists of pyritiferous chlorite schist.

In Nos. 4 and 5 *Open-cuts* the contact between the greenstone schist and a pyritiferous fine-grained porphyry (which in Nos. 4 and 5 is almost a felsite) is exposed. In the porphyry thin ironstone veins occur along planes of shearing and parting which are irregularly distributed. There are two sets of seams inclined at an acute angle. These seams make into thin veins of quartz in places. The greenstone schist at the margin is shattered and rubbly and disseminated with quartz veinlets and seams of pyrites.

Since the field work was completed at this centre, the Speakman Syndicate property has been equipped with a 10-head battery, but the results have, so far, been disappointing. If the gold were distributed uniformly throughout the body and gave an average prospect of 10 dwts., it would certainly be a good proposition. But the gold is apparently confined to certain seams, which although very numerous, are not universally distributed, since parts of the porphyry are devoid of them. The seams occur in parallel bands with intervening bands of barren rock. I should strongly advise prospecting the western contact of the porphyry dyke and schists as being the most likely locality in which to find payable stone. Before going in for any large expenditure on plant, etc., with the idea of treating the porphyry in bulk on a big scale (such bulk treatment would hardly pay on a small scale), very careful systematic and thorough sampling should be undertaken to test the bulk value of the porphyry. Also serious consideration should be given to the question of the cost of breaking the stone, on account of its hard nature at a comparatively shallow depth.

(2.) *Little Wonder*, G.M.L. 17, Location 50 (Smith and party). —This party is working a quarter of a mile east of Speakman's workings and on the western slope of a hill of amphibolite. The owners have here a quartz reef in massive amphibolite. The reef is dipping gently to the east at 15° and strikes north and south. The amphibolite is decomposed and bounded on the east by a band of hematite quartzite which outcrops across the top of the hill. On the west the amphibolite is bounded by greenstone schists and dykes of porphyry. The reef cuts out against the schist ending with an upward turn against the latter. As it dips east from the schists the reef becomes wider and is honeycombed underfoot. Near the schist

it is composed of opaque quartz, is narrow, and gives good prospects. Where it pinches against the schist it is richest and is said to go 3 ozs. per ton. The width varies from 6 inches to 18 inches.

In the schists a porphyry dyke runs parallel with the contact for some distance, and to the south turns in towards the contact and crosses. Where the porphyry dyke crosses the contact between the massive greenstone and schists the reef makes into a bulge of apparently poor stone. The quartz is pyritiferous, and when dollied, shows fairly coarse gold. The reef undulates gently as it dips to the east, and where the footwall bulges upwards the richest stone is found (*see* Fig. 14).



FIG. 14.

Cross section of Little Wonder Lease on Location 50.

(3.) *Battery Lease No. 1*, Location 50, worked by Irvine, Johnson, and Sullivan on tribute.—A considerable amount of work has been done on this lease, but most of the workings are inaccessible, owing to the decomposed nature of the ground. The tributers are taking out part of a gently inclined reef striking 347° and dipping about 20° east.

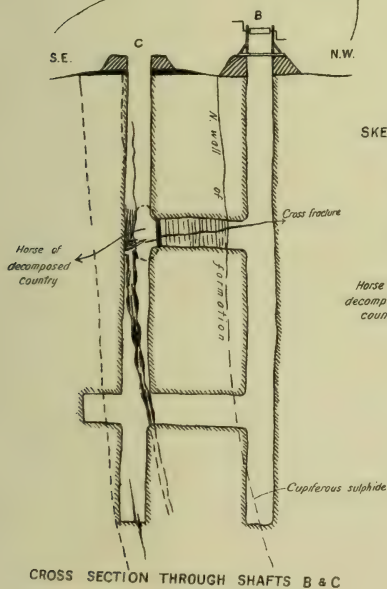
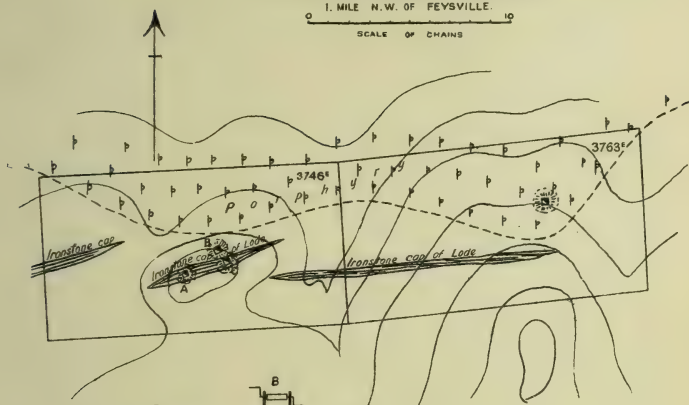
The reef occurs in a weathered greenstone and the workings are near the surface. A shoot of gold occurs in this reef pitching to the south-east, and 100 tons of this is said to have yielded 3000ozs. of gold. Parallel with this reef, and 45 feet below it, there is another reef of a similar character. There is probably a series of easterly dipping reefs in this lease and similar to the reef in the Little Wonder Lease. The present tributers are following the continuation of the shoot of gold and are prospecting for parallel reefs.

(4.) *Battery Lease No. 3*, Location 50 (O'Donnell and Cummings).—A shaft has been put down in a fine-grained greenstone and has cut a reef at about 30 feet. The reef is from 15 inches to 24 inches wide, strikes on a bearing of 219° and dips 17° to the south-east.

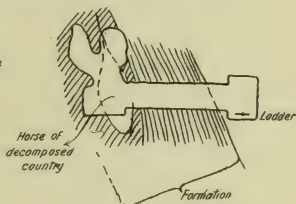
Clear transparent quartz occurs on the hanging wall side and contains crystals of tourmaline and calcite. Along the footwall the quartz is opaque and carries most of the gold. A small leader carrying free gold and ironstone projects from beneath the footwall.

SKETCH PLAN OF
HASSELL'S MINE
 KNOWN AS THE MICHAEL ANGELO LODE

1 MILE N.W. OF PEYSVILLE.
 0 10
 SCALE OF CHAINS



SKETCH PLAN OF 35 FT LEVEL



North of the shaft there occurs a dyke of porphyry striking to the north-east. The reef is not sufficiently opened up to show its relation to this dyke.

(5.) *The Michael Angelo Lode*, G.M.L. 3746E (Hassell and party).—Is situated half a mile north of the north-west peg of Feysville Townsite. This lode occurs in a fine-grained amphibolite almost alongside the latter's contact with porphyry country. The lode formation is 25 feet wide but does not carry gold right across. The gold is confined to narrow quartz seams in the schistose lode matter. At the surface the lode has a very ferruginous gossan, which becomes less ferruginous and more schistose with depth.

Three shafts have been put down (A, B, and C, Fig. 15), A and C on the lode, and B north of the lode.

Shafts B and C are connected by cross-cuts at 35 feet and 70 feet, and the total depth is 90 feet. At the 35ft. level there is a horse of country which looks like an unsheared portion of a shear zone. In the cross-cut on this level the formation is oxidised and has the appearance of a ferruginous schist with bands of ferruginous quartzite and opaque quartz parallel with the schist distributed in it. The quartz is mineralised and the gold appears to come from it and the ferruginous quartzite. In C shaft there is a ferruginous quartzite band of five feet in width and brecciated in places. Although the total width of the formation is 25 feet, the auriferous portion is only a fraction of this. Copper stains occur in the schists.

At the 70ft. level the formation looks like sheared greenstone with pyritic seams and quartz leaders in it which contain some copper pyrites.

In shaft A only oxidised matter is to be seen. It is sunk to 45 feet and shows ferruginous quartzite and opaline quartz with horizontal seams of secondary ironstone and kaolin along planes of surface parting. At the bottom there is three feet of ferruginous quartzite banded in places, and one foot of highly mineralised quartz.

No stone of commercial value was discovered in A shaft up to the time of my visit.

The following assay results, submitted by the owners, were obtained from samples collected in the lode, and submitted to three different assayers. The positions of the samples were not accurately kept and therefore do not give any clue as to what portion of the lode carries the gold.

Sample No.		1.	2.	3.
			dwts.	dwts.
1	from reef	14/-	13	11
"	2 " cuddy in shaft ..	40/-	12	23
"	3 " above 6	3/-	2	1
"	4 " bottom of shaft ..	17/-	32	52
"	5 " " " " " ..	trace.	trace.	trace.
"	6 " jasper band	300/-	70	38
"	7 " cross-cut	trace.	2	2

One sample gave 15 dwts. of gold, 16 ozs. of silver, and 4 per cent. of copper.

I understand that sample No. 7 was taken right across the lode in the cross-cut at 35 feet, and therefore gives the average value of the lode formations as 2 dwts. It appears, therefore, that although the lode formation is 25 feet wide only a fraction of this is auriferous. The gold appears to be contained in the quartzose portion of the formation and that occurs as vertical bands of quartzite and ferruginous quartzite from a few inches to two or three feet wide. The copper occurs only in narrow seams of pyrites. The previous record of this mine is 45 ozs. of gold from 115 tons of ore, or an average of 8 dwts. per ton.

Although the results of the work on this lode have so far proved disappointing, there may still be a chance for the mine as a low-grade proposition.

(6.) *Abandoned G.M.L. 2717E* has a vertical quartzose formation striking 350° across the lease near its northern boundary. The formation is brecciated in places, principally along vertical shear zones. The quartz is opaque. The country is a fine-grained greenstone with oblique shear lines dipping to the east, but not cutting through the formation.

(7.) *On Abandoned G.M.L. 1242E* clear quartz reefs occur in greenstone schist, striking 340° . The reefs are vertical, but have leaders coming in from the foliation planes of the schist. A cross-section east and west, exposed in a deep costeen, shows the reef as follows (Fig. 16).

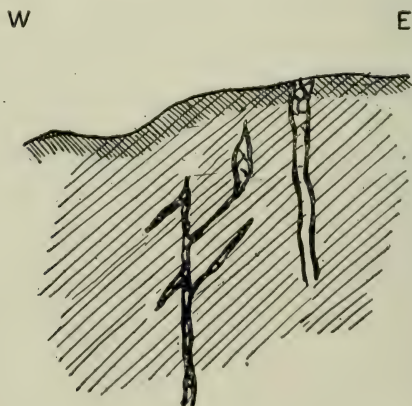


FIG. 16.

Section of Reefs on G.M.L. 1242E, Feysville.

Still further north abandoned G.M.L. 2708E has two series of reefs. An older series striking north-east and dipping 70° to the north-west containing pyrites and composed of opaque quartz. A later series of cross leaders cut through the above and fault them slightly, but are composed of a clear glassy quartz (Fig. 17).

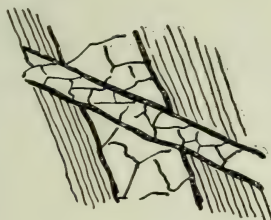


FIG. 17.

Section of Reefs on G.M.L. 2708E, Feysville.

The glassy kind of quartz reef that occurs in the greenstone schists becomes in places very wide, and outcrops in large blows of buck quartz.

The following is a table of the gold returns for the Feysville mining centre including Location 50, as recorded by the Mines Department. The totals give the good average of 14.5 dwts. per ton.

FEYSVILLE.

Year.	Name of Claim.	Dollied and Alluvial.	Ore Treated.	Gold therefrom.
1898	Michael Angleo Lode, G.M.L. 3746E	ozs. ..	tons. 114.85	ozs. 45.37
1900	Rosina, G.M.L. 2684E ..	1.10	10.50	3.00
	Block 50, Hampton Proper- ties, Ltd.	..	712.00	436.00
Previous to 1901	Eagle Hawk United, G.M.L. 3770E	..	31.00	60.71
1901	Do. do. ..	23.00	77.00	125.10
	Block 50, Hampton Proper- ties, Ltd.	8.00	1,483.00	422.15
	Kitchener	..	20.00	14.75
	Rosina, G.M.L. 2684E ..	..	7.00	4.80
	Carried forward ..	32.10	2,455.35	1,111.88

FEYSVILLE—*continued.*

Year.	Name of Claim.	Dollied and Alluvial.	Ore Treated.	Gold therefrom.
		ozs.	tons.	ozs.
	Brought forward ..	32·10	2,455·35	1,111·88
1902	Block 50, Hampton Properties, Ltd.	..	551·00	877·70
	Levetts Boulder, G.M.L. 3941E	26·00	..	..
	Rosina, G.M.L. 2684E ..	..	16·00	9·50
1903	Eagle Hawk United ..	..	91·00	94·56
	Block 50	..	1,373·00	1,396·14
1904	Block 50	..	1,622·00	699·88
1905	Block 50	..	409·00	373·20
	Rosina	..	16·00	13·63
1906	Block 50	..	133·00	115·55
	Western Star, G.M.L. 4221E..	..	30·50	23·86
1907	Block 50, Hampton Plains Estate (1906)	..	25·00	38·63
	Block 50, Hampton Properties	..	65·00	82·86
1908	Block 50, Hampton Plains Estate (1906)	..	60·00	70·19
	Block 50 Hampton Properties	..	45·00	55·14
1909	Block 50, Hampton Properties	6·26	86·15	114·24
	Sundry Claims	..	59·00	24·43
1910	Block 50, Hampton Properties	..	218·00	180·27
	Sundry Claims	..	75·00	18·38
1912	Block 50, Hampton Properties	..	4·20	7·60
1913	Block 50, Hampton Properties	..	161·48	79·97
	Sundry Claims	..	22·01	5·92
		64·36	7,517·69	5,393·53
				64·36
	Total Gold	..	..	5,457·89

Average 14·5dwts. per ton.

THE COUNTRY WEST OF LAKE LEFROY.—This tract of country has no working mines in it north of Widgiemooltha, and generally speaking, the majority is not promising auriferous country owing to the large development of metamorphosed sediments and granite.

However, the belt extending from Mt. Marion to Yilmia Trigonometrical Station is composed of greenstones and greenstone schists, and is country in which payable auriferous lodes and reefs might occur.

Also the western side of Location 48 is country which is part of a proved auriferous belt, as shown by table below.

Besides these there are two minor belts of greenstone, one crossing the Coolgardie-Widgiemooltha Telegraph Line at the 35-mile post, and another which is probably the northern extremity of the Widgiemooltha belt of country. The latter follows the Widgiemooltha road from the 28-mile post southwards passing to the west of Emu Rocks, which is 10 miles north of Widgiemooltha.

As regards other minerals than gold, the geological features along the granite contact are favourable for the discovery of such minerals as cassiterite, scheelite, wolfram, molybdenite, and amblygonite.

The following is a table showing the gold returns from the Hampton Plains Estates, Locations 45, 48, and 53, taken from Mines Department statistics:—

HAMPTON PLAINS.

Year.	Name of Claim.	Dollied and alluvial.	Ore Treated.	Gold therefrom.
		ozs. alluvial.	tons.	ozs.
1899	Merry Hampton Block 48 ..	4,913·45	110·00	53·40
	Ajax Block 53 ..	..	67·00	128·55
1901	Block 48, Hampton Plains Estate	..	29·00	9·60
1902	Do. do. ..	..	12,836·00	1,499·45
1903	Do. do. ..	..	7,486·00	1,214·42
	Block 53	Dollied. 421·00	..	..
1904	Block 48, Hampton Plains Estate	..	101·00	30·29
1907	Do. do. ..	..	.. extras	9·89
1908	Block 48, Hampton Properties	38·63	27·75	41·71
1909	Do. do. ..	14·12	24·00	34·92
1911	Do. do. ..	..	21·40	41·81
		5,387·20	20,702·15	3,064·04 5,387·20
	Total Gold	..	..	8,451·24 4,913·45
	Total Gold without Alluvial	..	..	3,537·79

Average—3·4dwts. per ton.

CONCLUSION.—The ore deposits that have been described in the above report can be classified as follows:—

- Quartz reefs (a) in porphyry;
- (b) in greenstone;
- Lode—Formations in shear zones;
- Stockworks; and
- Alluvial deposits.

The Quartz Reefs are most plentifully represented in the district and may be divided into two classes according as they occur in porphyry or in greenstone. The majority belong to the latter subdivision.

In the porphyry rock they represent fissures formed by fracture and faulting under compression as at Golden Ridge.

In the greenstones the reefs are probably of the same origin under less confined conditions; for example, the Little Wonder Reef and the reefs in Leases 1 and 3 of Location 50.

The auriferous quartz reefs are generally composed of opaque quartz which is often fractured and granulitised, and are intersected by a series of glassy transparent quartz veins which are generally non-auriferous and of later age. The glassy quartz veins are practically unaffected by earth movements and are probably the tail end of the latest granite intrusions.

The Lodes are practically unrepresented in the mines of the district except for the formation on Hassell's Michael Angelo Lode at Feysville. There is, however, no reason why lodes should not be discovered in the future, especially in Location 50 of the Hampton properties and Location 48 of the Hampton Plains Estate.

Stockworks.—Porphyry dykes in which seams of quartz and ironstone have been formed by the filling of shear and parting planes. These seams occur in such profusion in the dyke and are individually so thin that it would not pay to mine them separately. If bulk treatment of the dyke is the only practical way in which to extract the gold from the numerous narrow seams in a dyke, then such a formation is best called a stockwork. The porphyry on Speakman's property at the Hampton Boulder belongs to this class of ore deposit.

Alluvial Deposits.—These are likely to be found anywhere in the greenstone belts.

Alluvial patches occur at Boorara, Feysville, Location 50, and Location 48, and it is most likely that more alluvial gold will be found in these localities, especially on Location 48 and surroundings, as blacks often bring in small slugs to the Woodline Stores from the latter locality.

Exploration of worked out patches of alluvial might lead to the discovery of gold reefs and lodes from which such patches were derived, as there is no doubt that gold in this country does not travel far from its source.

INDEX.

	Page
Aeolian Plain Deposits	13, 36
Age of Kalgoorlie Rocks	42
Agglomerates (Greenstone)	13, 16, 17, 18
Agglomerates (Porphyrite)	13, 21
Alluvial Deposits	70
Alluvium	13, 35, 37
Amphibolites	13, 14, 15, 16, 32, 62, 63, 65
Andalusite Schists	21, 33
Arkoses	13, 35
Assays, Michael Angelo Lode	65
Ballarat (Victoria)	48
Battery Lease No. 1, Feysville	60, 64, 70
Battery Lease No. 3, Feysville	60, 64, 70
Bendigo Reefs (Victoria)	55
Black Flag	40
Blatchford, T.	24, 34, 42
"Blow" Reef, Boorara	58
Boorara	10, 11, 14, 17, 25, 26, 43, 44, 58, 70
Boorara Mining Centre	9, 56
Boulder	9
Breccias	13, 16, 17, 42, 46, 49
Brecciated Zones	46
Bulletin 42, G.S.W.A.	9
Bulletin 56, G.S.W.A.	9, 12, 35, 42
Bulletin 59, G.S.W.A.	9
Bulong	34
Bulong Road	24, 26, 37, 44, 58
Campbell, W. D.	34
Chlorite-talc-ferrous Carbonate Rock	25
Cleavage	38
Cohen's Reef, Walhalla (Victoria)	55
Compression Faults	39
Conglomerates	13, 35
Conglomerate Schists	35
Contact Metamorphism	21, 28, 33, 43
Coolgardie	9, 42
Coolgardie Auriferous Belt	32, 33
Coolgardie-Widgiemooltha Road	33
Cores from Bores, Golden Ridge Mine	29, 30, 31
Corsair Leases	58
Country West of Lake Lefroy	9, 10, 68
Darling Ranges	34
Daubree	50
Dip Faults	39, 40
Dolerite (Amphibolised)	24, 25, 26
Dolerite (Hornblende)	17
Dolerite (Quartz)	15, 26
Dry Lake Country	11
Dry Lake Deposits	13, 36
Dugdale, G. R.	9
Duplex Hill	11, 34

INDEX—continued.

	Page
Edjudina Rock Series	12
Emu Holes	26
Emu Rocks	29
Erosion	10, 11, 36
Farquharson, R. A. 9, 14, 17, 18, 19, 22, 24, 25, 26, 27, 28, 29, 30, 32, 38, 42, 62	
Faulting	39, 40, 41, 43, 47, 49, 55
Feysville	11, 15, 18, 25, 26, 27, 33, 36, 40, 62, 70
Feysville Greenstone Belt	14, 15
Feysville Mining Centre	9, 60, 67
Fine-grained Greenstones	17
Flat-topped Rises	11
Folding	38
Foliation	38, 43
Fractures	46, 47, 49, 50
Gabbro	13, 24, 25, 26
Gabbro (Norite), Newer	13, 24, 34
Garnetiferous Schists	22, 33
Gibson, C. G.	9, 11, 12, 15, 21, 22, 24, 42
G.M.L. 1242E, Feysville	66
G.M.L. 2717E, Feysville	66
G.M.L. 2708E, Feysville	67
Golden Ridge District	11, 18, 22, 25, 26, 27, 29, 45, 70
Golden Ridge Greenstone Belt	14, 15
Golden Ridge Mine ... 9, 14, 17, 26, 29, 39, 40, 43, 44, 45, 57, 58, 59, 70	
Golden Ridge Mining Centre	9, 10, 43
Gold Yields	44, 59, 67, 68, 69
Grace Darling Lease, Boorara	58
Granite	13, 24, 32, 33
Granite (Biotite)	27
Granite Porphyry	27
Graphitic Clay Breccia	22
Graphitic Slates and Schists	22, 23, 24, 45, 46, 47
Greenstones	10, 11, 13, 14, 17, 47, 49, 62, 64, 66, 68, 70
Greenstone Schists	49, 58, 60, 63, 66, 68
Grits	21
Gympie (Queensland)	48
Hampton Boulder Lease (Speakman Syndicate and Workings) 10, 28, 60, 70	
Hampton Boulder Mine	16
Hampton Plains Estates (<i>see also under "Locations 45, 48, 53"</i>) ... 69, 70	
Hampton Properties, Limited (<i>see also under "Location 50"</i>) ... 9, 70	
Hannan's Lake	11, 12, 15, 21, 36, 41, 45
Higher land, The	10
Hornblende Dolerite	17
Hornblende Porphyrite	19
Horse Rocks	11, 22, 33
Huronian Series of America	42
Intrusive Rocks	13, 17, 24
Johnson Lakes, Bremer Ranges	36
Johnson's "Materials of Construction"	50
Jutson, J. T.	36
Kalgoorlie—References to Geology of ... 9, 12, 13, 14, 15, 18, 24, 25, 35, 40, 41, 42, 47	

INDEX—*continued.*

	Page
Kalgoorlie Rocks—Age of	42
Kalgoorlie Series	13, 14, 42
Keeweenawan Series of America	42
Knotted Schists	33
“Kopai”	36
Kurrawang	12, 38
Kurrawang Lakes	11, 40, 41
Kurrawang Series	12, 13, 35, 42
Kurrawang Syncline	35, 38, 41, 42
Lake Lefroy	11, 12, 36
Lake Lefroy—Country west of	9, 10, 68
Lakes—	
Dry Lake Country	11
Migration of	36
Salt	10, 11, 36
(See also under Hannan's Lake, Lake Lefroy, Kurrawang Lakes.)	
Lakeside	11, 36, 41
Lakeside Railway Station	12
Larcombe, C. O. G.	21
Laterite	13, 37
Lindgren, W.	50
Little Wonder Lease, Feysville	60, 63, 70
Location 50 of the Hampton Properties, Limited	9, 10, 16, 17, 25, 26, 27, 28, 41, 60, 61, 63, 64, 67, 70
Location 45 of the Hampton Plains Estate	69
Location 48 of the Hampton Plains Estate	32, 33, 60, 61, 68, 69, 70
Location 53 of the Hampton Plains Estate	16, 69
Lode formations	58, 60, 65, 66, 70
Mabie's Old Homestead	35
Maclaren, Dr. J. M.	24, 40, 41, 42
Maitland, A. Gibb	42
Merry Hampton Battery	60
Metamorphism (see Contact Metamorphism and Regional Metamorphism).	
Mica	33
Mica Schists	21
Michael Angelo Lode, Feysville	60, 65, 70
Migration of Lakes	36
Mineralisation of Reefs	52
Montgomery, A.	57
Mount Monger Thrust Plane	40
Mt. Bellow Mine, Ballagundi	58
Mt. Goddard	11, 16, 25, 28
Mt. Herbert	17, 18
Mt. Hunt	15, 18, 41
Mt. Jackson district	12, 35
Mt. Marion	68
Mt. Marion—Yilmia Trig., Greenstone Belt	14, 16
Mt. Shea	10, 11, 15, 21
Norite	13, 24, 34
Norseman	34
Ore Genesis	53
Overthrust faults	40, 41, 42

INDEX—*continued*.

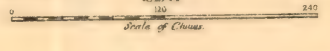
	Page
Pegmatite Dykes	33
Peridotite and Derivatives	24
Physiographical Features	10
Planes of Parting	39, 61
Porphyries	13, 24, 26, 27, 28, 29, 30, 31, 32, 45, 60, 70
Porphyrite Agglomerates	13, 21
Porphyrite (Intrusive)	13, 24, 26, 32
Porphyrite (Volcanic)	13, 18, 19
Pre-Cambrian Rocks	13, 42
 Quartz Dolerite	15, 26
Quartzites	15, 47
Quartzitic Schists	60
Quartz Reefs	27, 43, 49, 51, 52, 53, 55, 58, 63, 64, 66, 67, 70
 Rain marks in alluvial cement	37, 38
Ranges and Ridges	10, 11
Recent (Superficial) Deposits	13, 35
Red Hill	11, 33, 35
Red Hill—Horse Rocks Road	29, 35
Regional Metamorphism	13, 14, 18, 34, 38, 42
Reversed Faults	39, 41, 42
 Salt Lakes	10, 11, 36
Sand Dunes	36
Sand Plains	11
Sandstones	22
Schists (<i>see</i> under mica schists, andalusite schists, garnetiferous schists, knotted schists, graphitic slates and schists, talc-chlorite schists, quartzitic schists, and greenstone schists).	
Sedimentary Rocks	11, 13, 15, 21, 40
Serpentine	13, 25
Shearing	39, 43
Sills	13, 16, 42, 46
Simplex Hill	11, 34
Slates	13, 21, 22
Slate Well	11
Somerville	15
Somerville Woolabar Greenstone Belt	14, 15
Speakman Syndicate	10, 60, 70
Stockworks	70
Strike Faults	39
Structural Features	38
Succession of Rocks	12, 13
Syncline (Kurrawang)	35, 38, 41, 42
 Talc-chlorite Schists	45, 47
Thomson, Dr. J. A.	24, 25, 40, 41, 42
Topography	10, 12
Tourmaline	33
Travertine	13, 36
Tuffs	13, 17, 18
 Unconformity	12, 13, 35
 Valleys	10, 11
Vegetation	12
Volcanic Agglomerates	13, 15, 16, 17, 18

INDEX—*continued.*

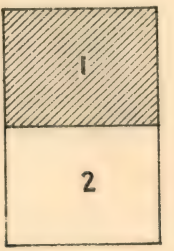
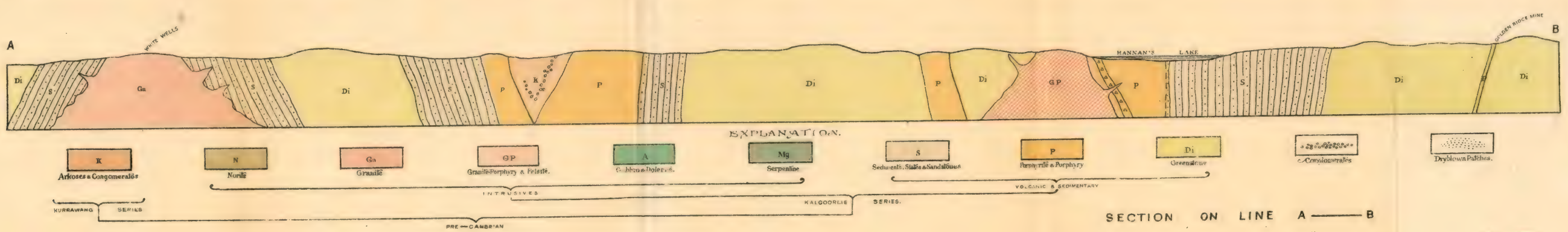
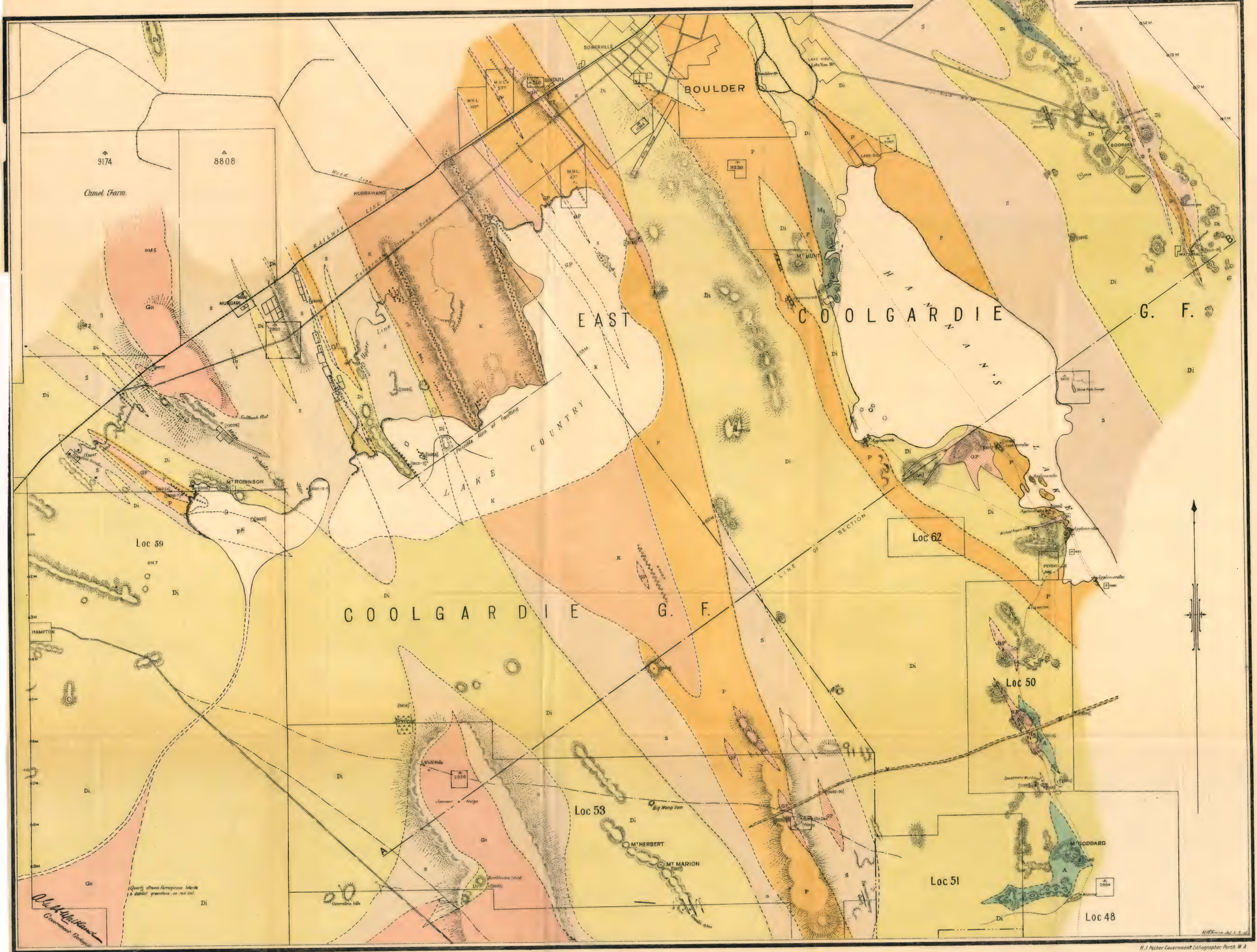
	Page
Waterfall Townsite and Leases	43, 44, 45, 57
Widgiemooltha	9, 11, 12, 17, 29, 68
Widgiemooltha Road	16, 26, 28, 31
Wongi	10, 34, 41
Woolabar	11, 16, 17, 25
Yilmia Trigonometrical Station	10, 21, 68



GEOLOGICAL MAP & SECTION
OF
PART OF COOLGARDIE AND EAST COOLGARDIE GOLDFIELDS
SOUTH OF THE EASTERN GOLDFIELDS RAILWAY.
C. G. Gibson, Assistant Geologist (Boulder Area) & C. S. Houston, B.M.E., Field Geologist.
1923-24



BULLETIN NO. 65 PLATE I

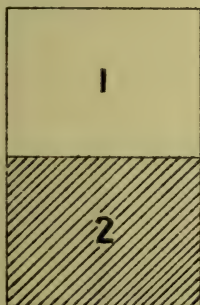


L A K E

A Gibb Maitland
Government Geologist

R. P. Green, del. 17. 13

H. J. Pelher, Government Lithographer, Perth, W. A.





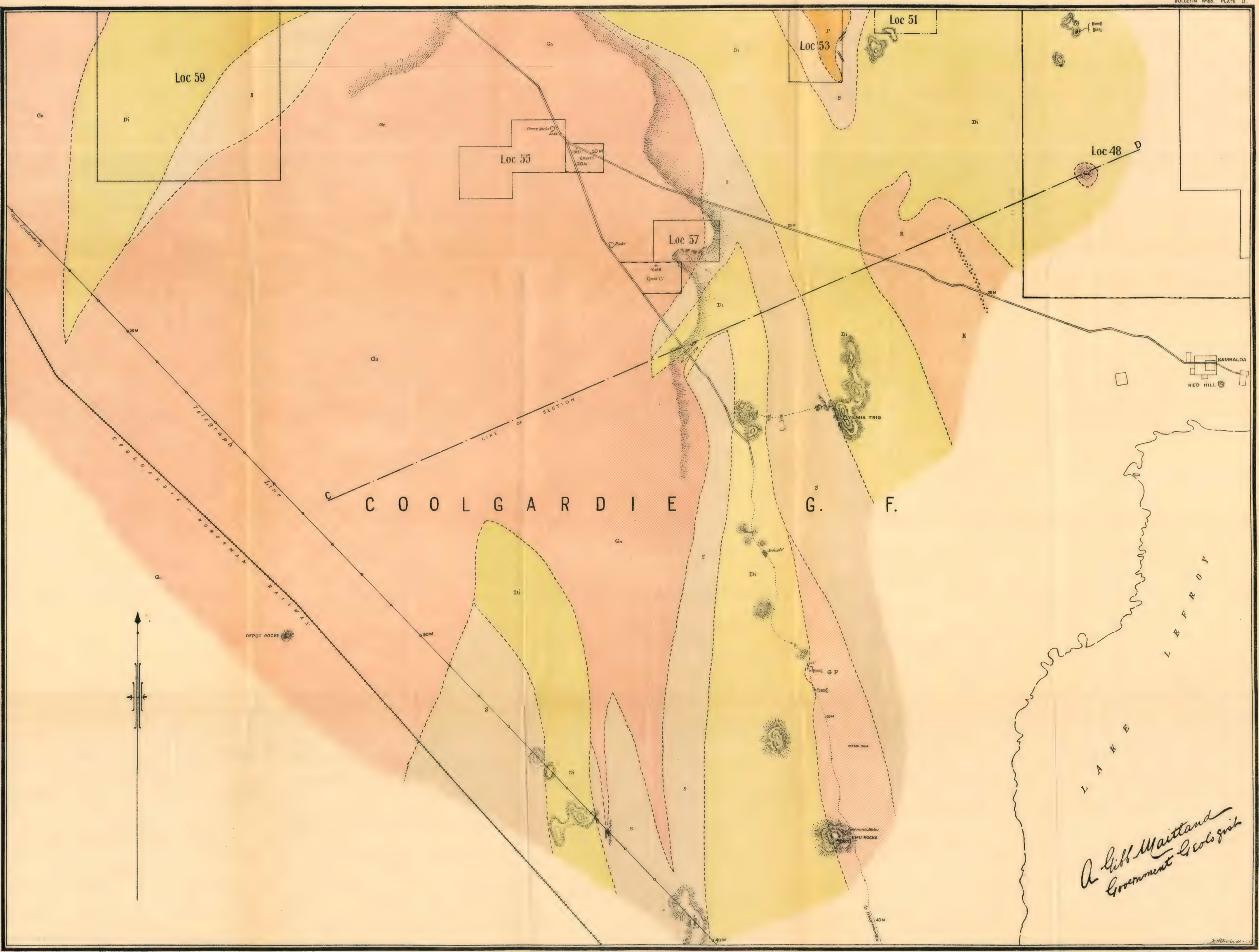
Hon P Collier M.L.A.
MINISTER FOR MINES

GEOLOGICAL MAP & SECTION
OF
PART OF COOLGARDIE AND EAST COOLGARDIE GOLDFIELDS
SOUTH OF THE EASTERN GOLDFIELDS RAILWAY.

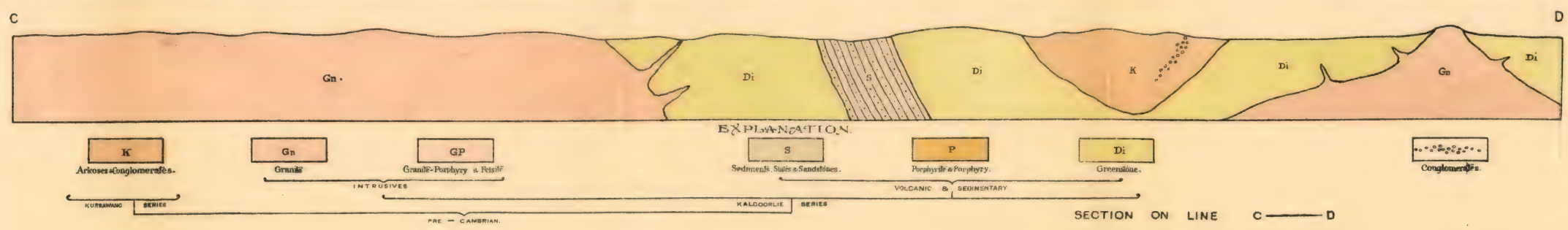
C. S. Housman, B.M.E. Field Geologist.

1918-14
Scale of Chains

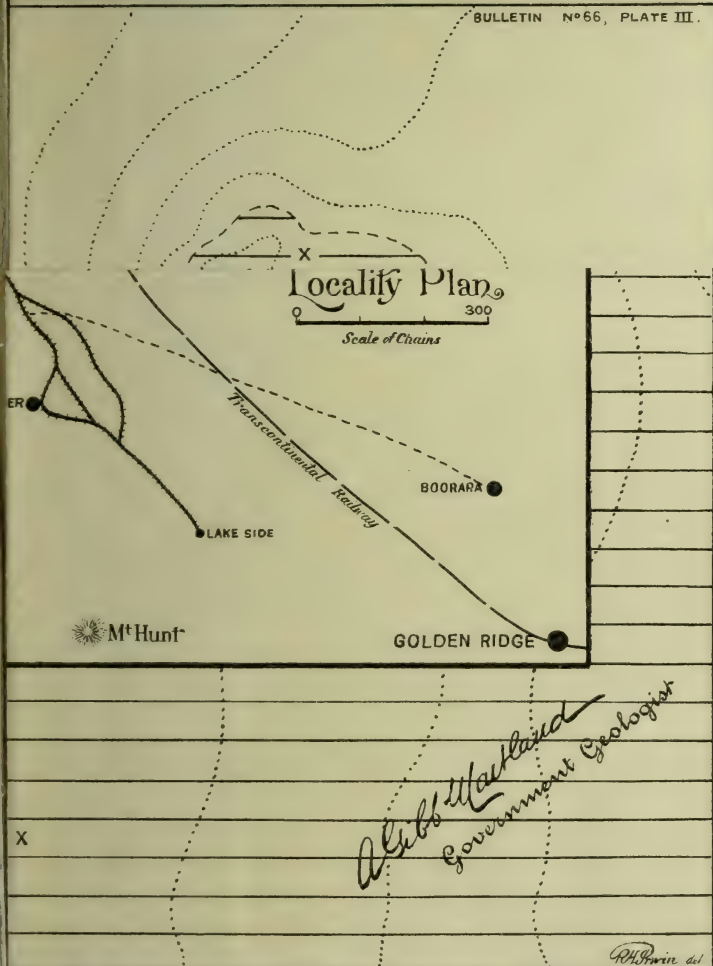
BULLETIN NO. 66, PLATE II.



*A Gift Maitland
Government Goldfields*

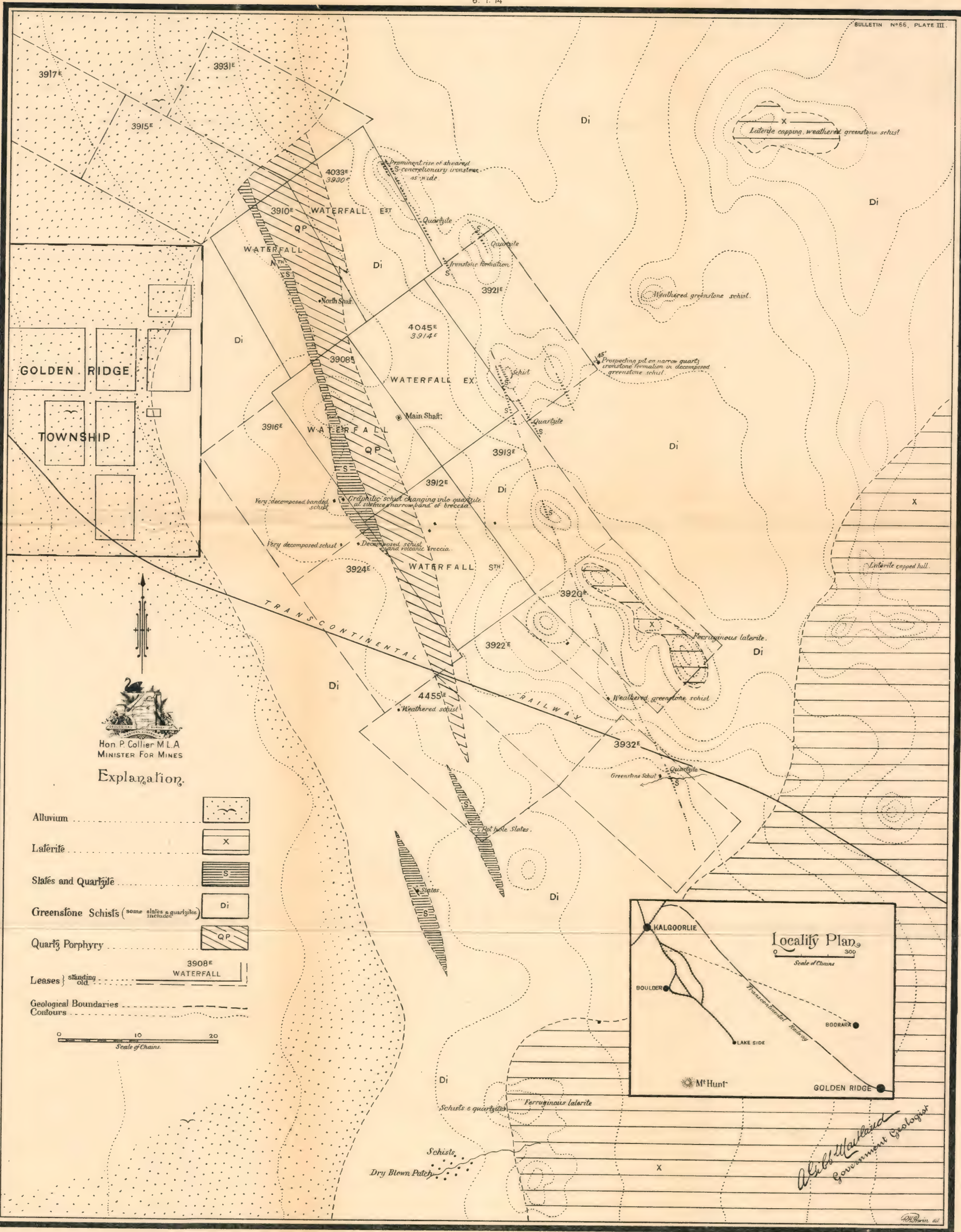


H.J. Palmer Government Lithographer Perth, W.A.



C. S. HONMAN ~~_____~~ FIELD GEOLOGIST.
6. 1. 14

BULLETIN N°66 PLATE III



Robt MacLeod
Government Geologist

R.H. Rabin

90

Hubb
Gover

3910^E

3908^E



Hon P. Callaghan M.L.A.
MINISTER FOR MINES

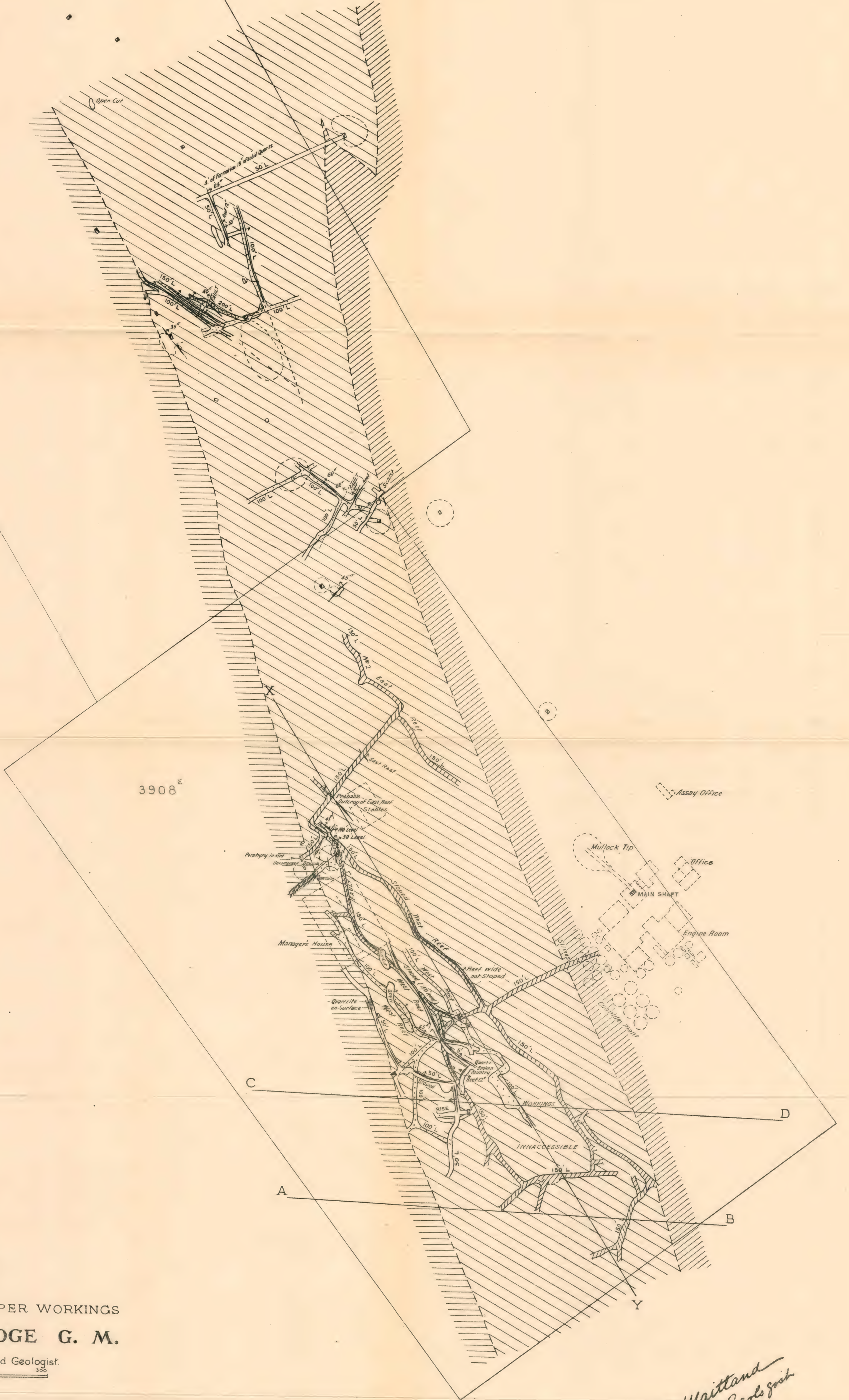
GEOLOGICAL MAP OF UPPER WORKINGS
OF
THE GOLDEN RIDGE G. M.

BY
C. S. Honman B.M.E. Field Geologist.

Scale of Feet.
0 100 200 300

Explanation.

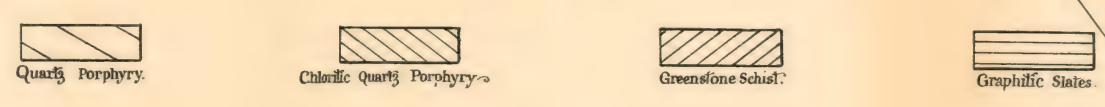
Chloritic Quartz Porphyry	
Greenstone Schist	
Slates	
50 FT Level	
100 " "	
150 " "	
200 " "	



*A. G. Maitland
Government Geologist*

GEOLOGICAL MAP OF LOWER WORKINGS
OF
THE GOLDEN RIDGE G. M.

BY
C. S. Honman B.M.E. Field Geologist:
Scale of Feet
0 100 200 300



200' Level.

300' Level

400' Level.

500' Level.

G.M.L. 3908.

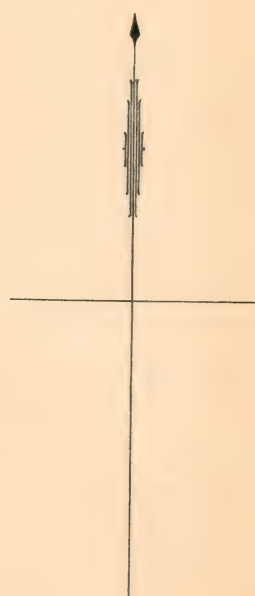
*A. G. Maitland
Government Geologist*



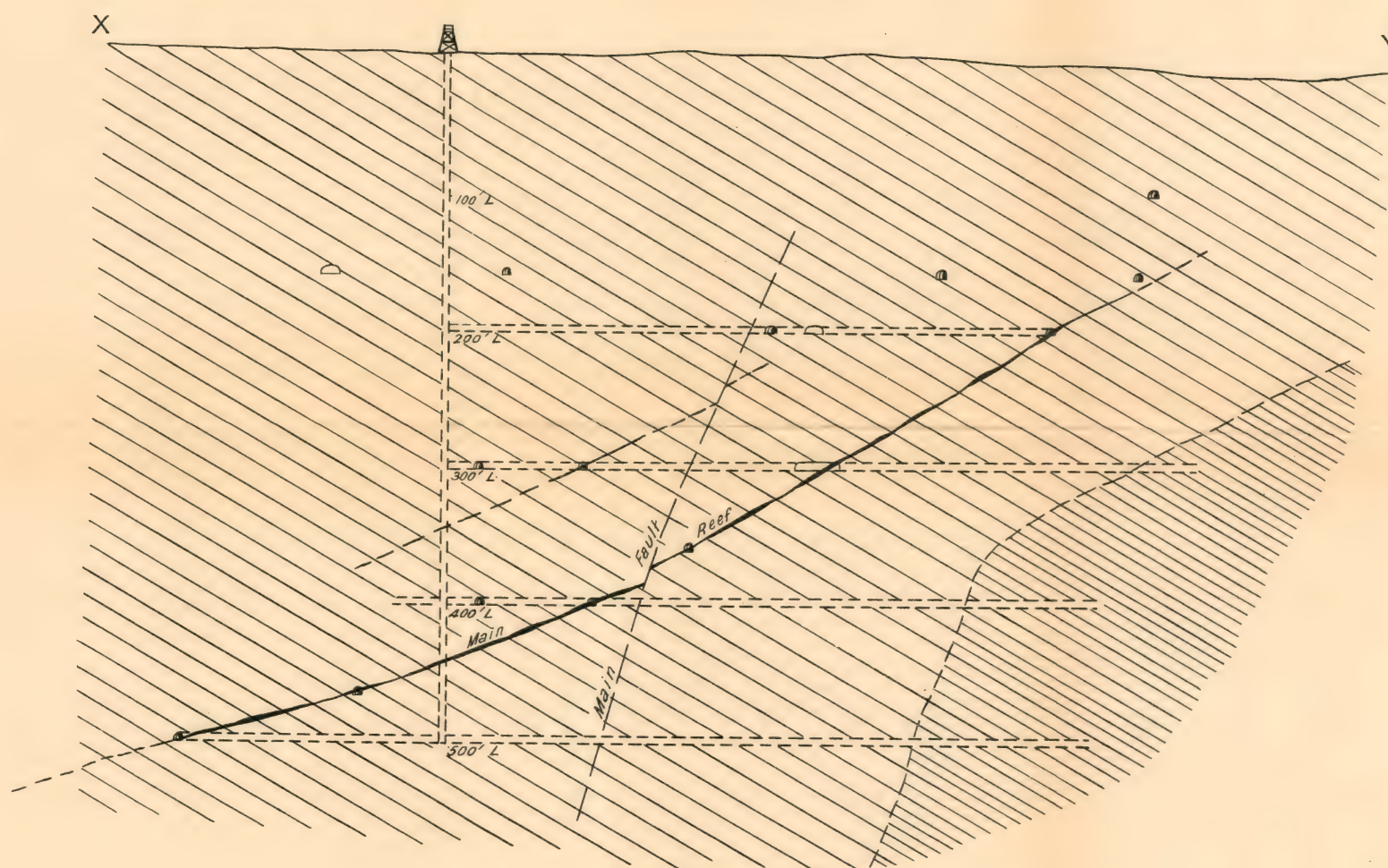
GEOLOGICAL SECTIONS OF
THE GOLDEN RIDGE G. M.

EAST COOLGARDIE G. F.

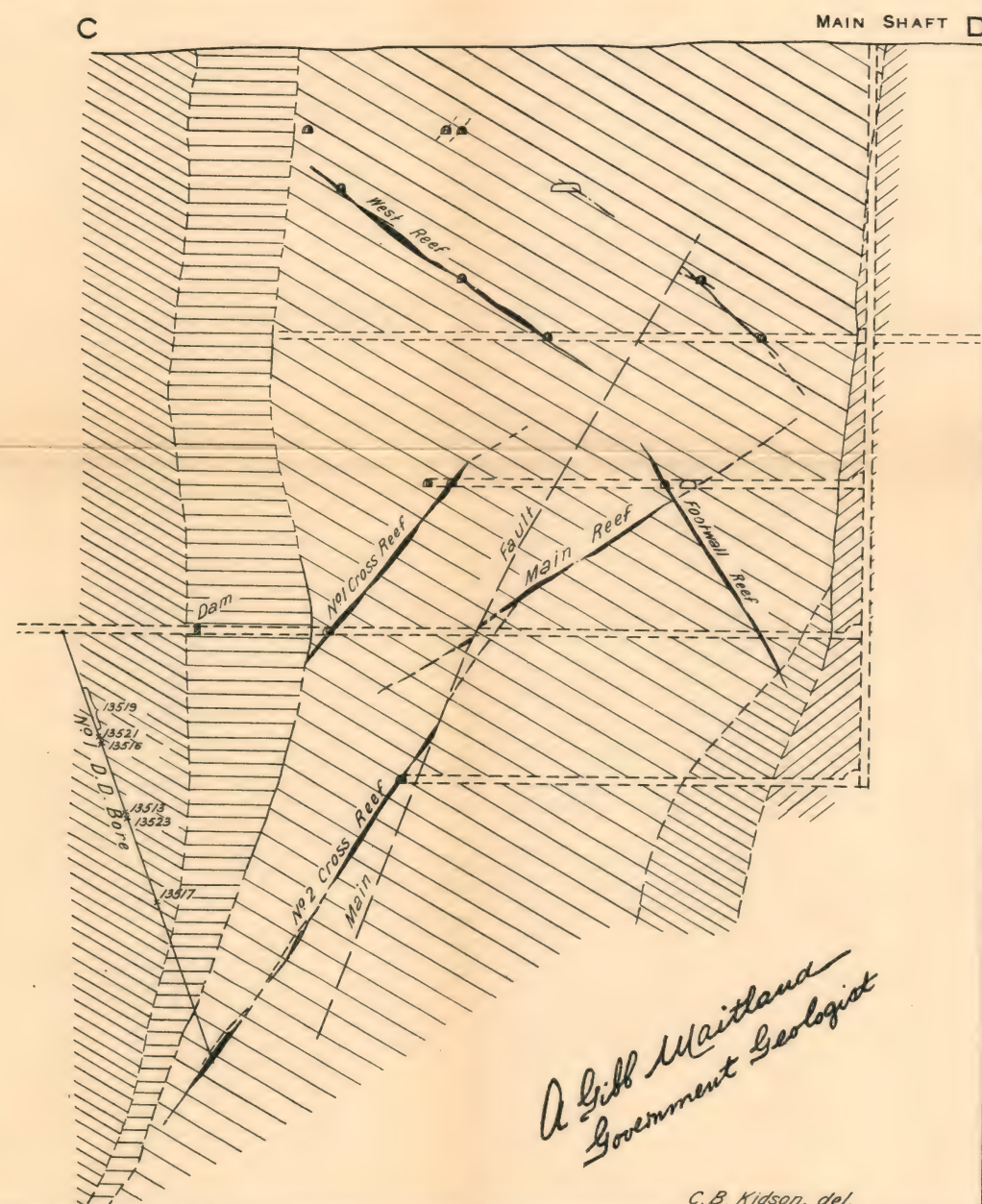
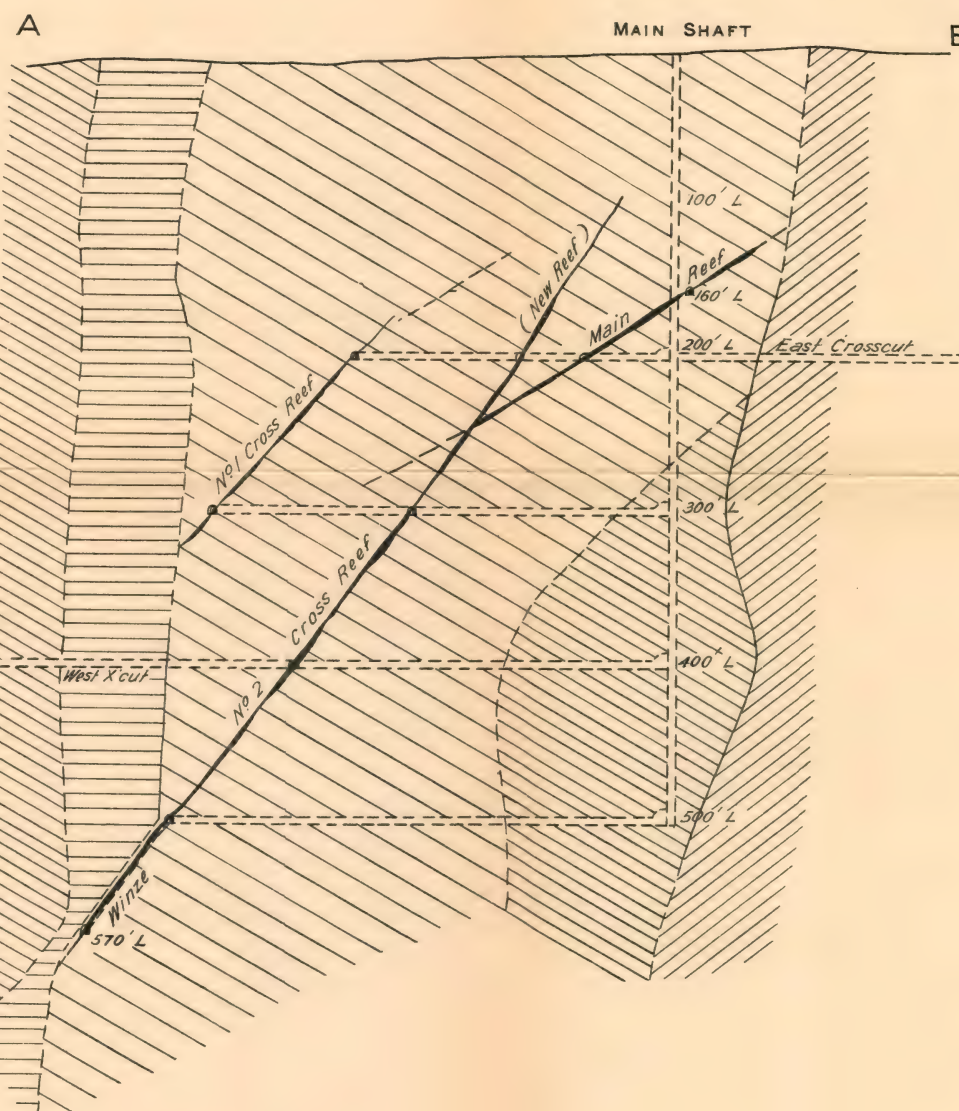
Scale of Feet



LONGITUDINAL SECTION.

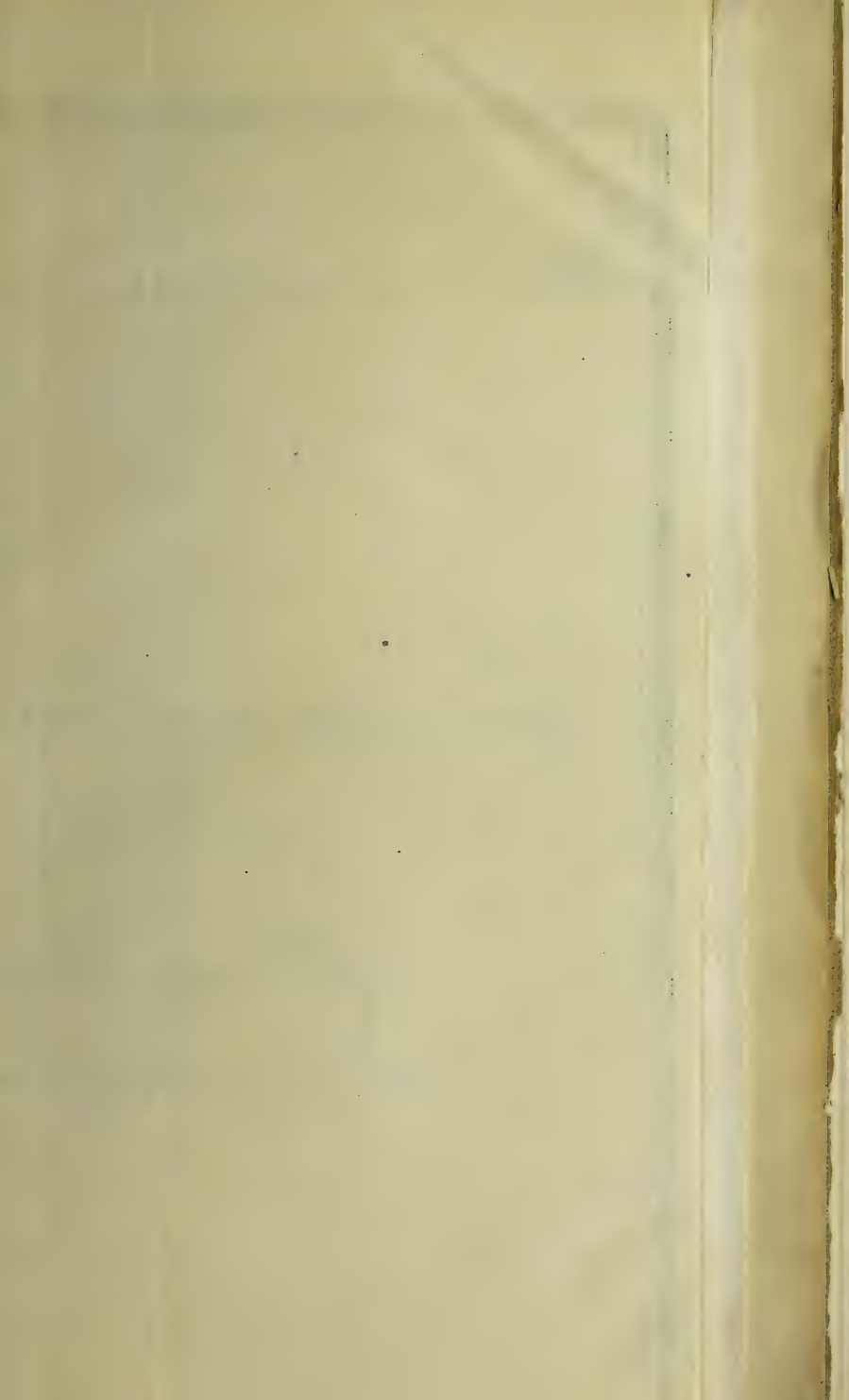


CROSS SECTIONS.



A. Gibb Maitland
Government Geologist

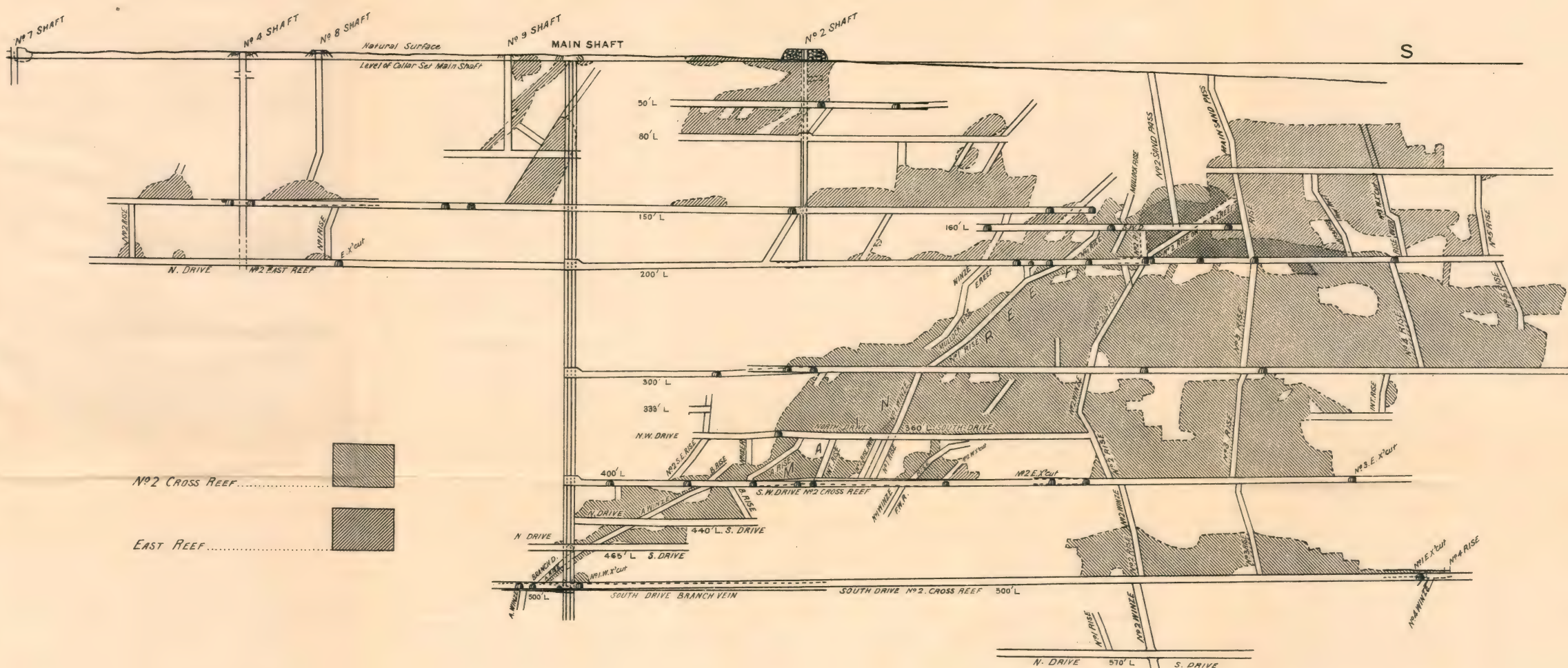
C. B. Kidson, del.



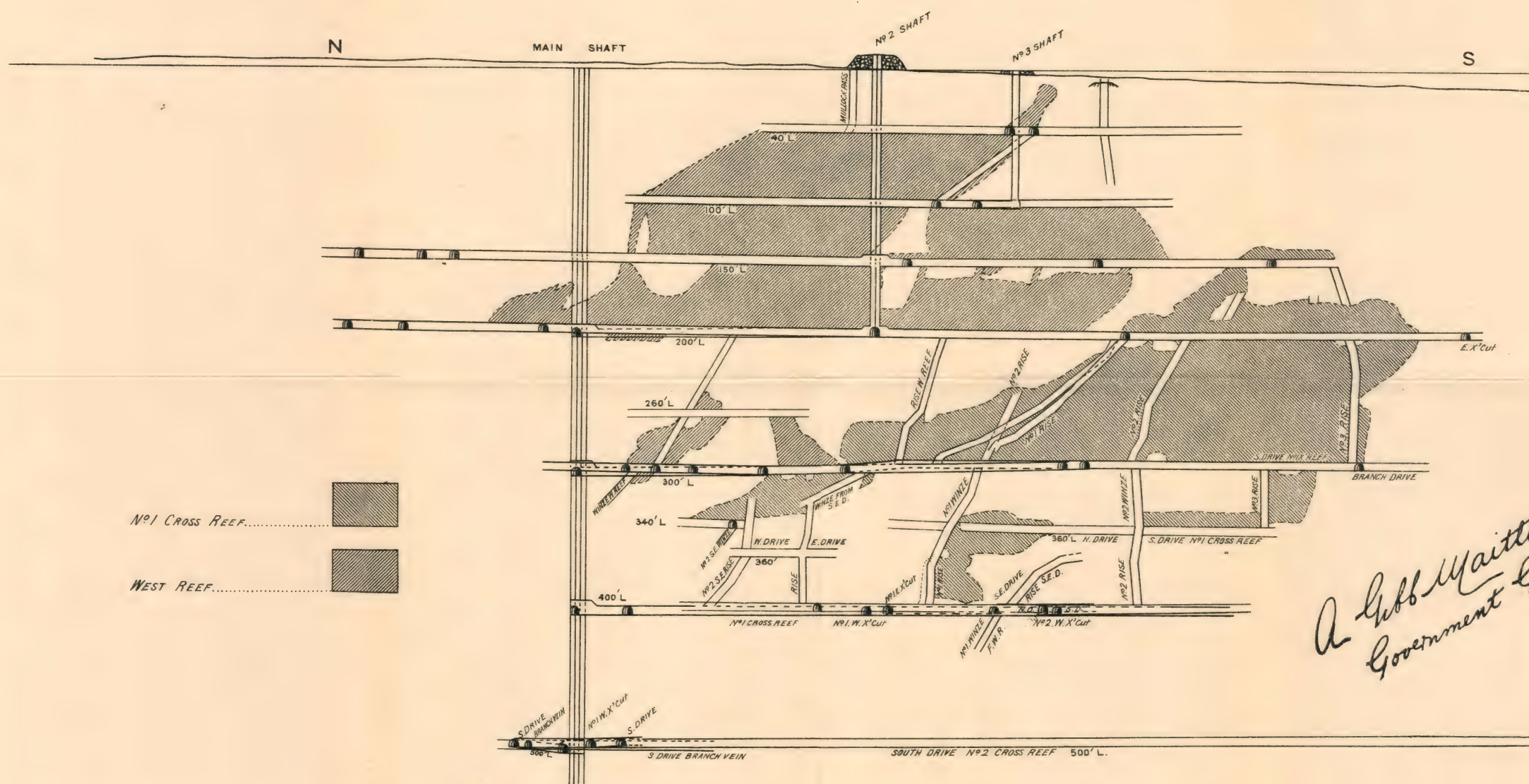


THE GOLDEN RIDGE G. M.

LONGITUDINAL SECTION OF WORKINGS, EAST REEF & N°2 CROSS REEF.



LONGITUDINAL SECTION OF WORKINGS, WEST REEF & N°1 CROSS REEF.



*A. G. Maitland
Government Geologist*



SECTIONS OF VARIOUS GEOLOGICAL FEATURES OF THE GOLDEN RIDGE G. M.

BY
C. S. Honman Field Geologist



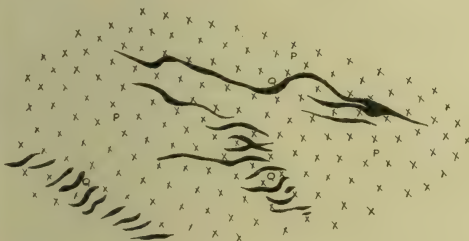
SECTION
N°1 CROSS REEF 200 FT L



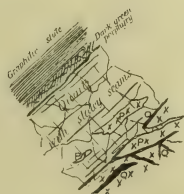
ROOF OF DRIVE



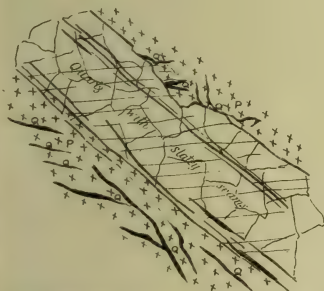
MAIN REEF 200 FT L LOOKING SE



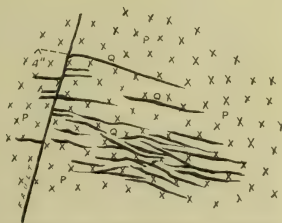
WEST WALL OF FOOTWALL REEF 400 FT L SOUTH END



N°2 CROSS REEF IN WINZE AT 550 FT
LOOKING NW



N°2 CROSS REEF 550 FT L. LOOKING SE.



WEST WALL OF N°2 CROSS REEF, 500 FT L. OVER WINZE.

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Explanation

Greenstone
(Normative 5001)

Di

Quartz Porphyry

P

Sugared Porphyry
a Quartz Schist

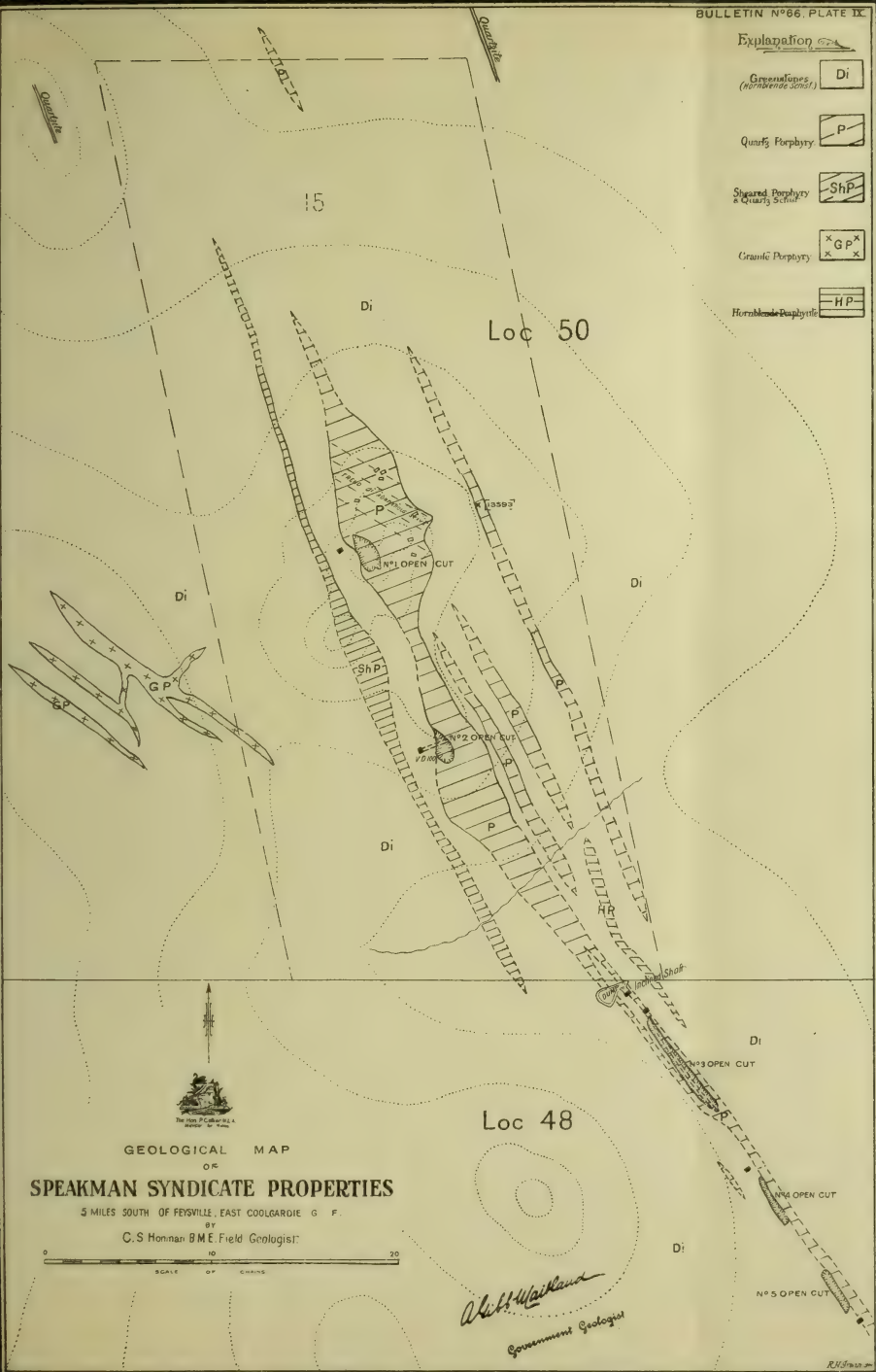
ShP

Granite Porphyry

GP

Hornblende Diaphyrite

HP

GEOLOGICAL MAP
OF

SPEAKMAN SYNDICATE PROPERTIES

5 MILES SOUTH OF FEYSVILLE, EAST COOLGARDIE G. F.

BY
C. S. HONNAN B.M.E. Field Geologist0 10 20
SCALE OF MILES0 10 20
SCALE OF KILOMETERS

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W 52 geol Survey.
V. 67

1916.

WESTERN AUSTRALIA.

MAY 12 1917

GEOLOGICAL SURVEY.

BULLETIN No. 67.

Analyses of Western Australian Rocks, Meteorites, and Natural Waters,

BY

EDWARD S. SIMPSON, B.E., B.Sc., F.C.S.,
Government Mineralogist and Chemist.

Issued under the Authority of
THE HON. R. T. ROBINSON, M.L.A., MINISTER FOR MINES.

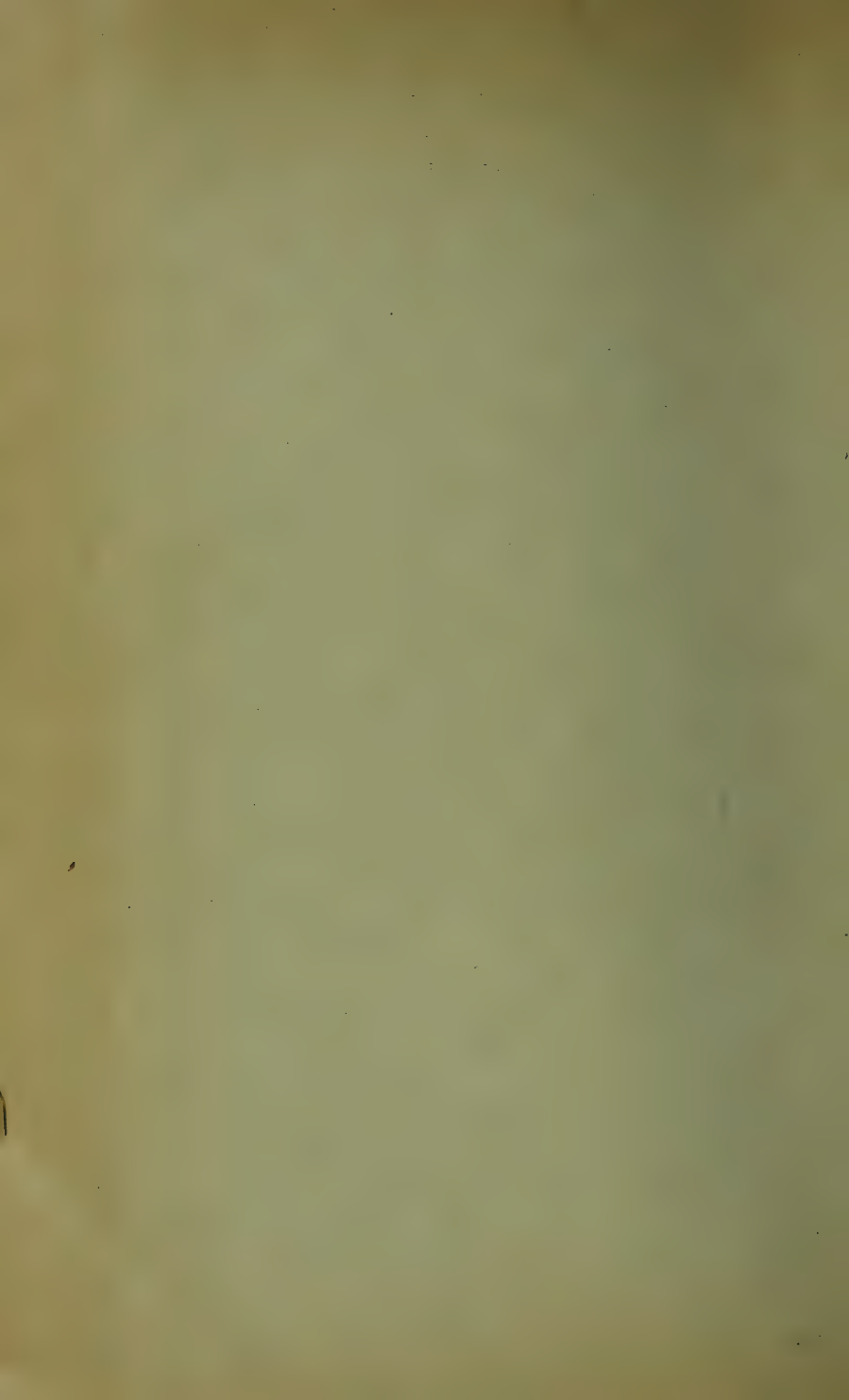
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1916.



1916.

WESTERN AUSTRALIA

UNIVERSITY OF WESTERN AUSTRALIA
MAY 12 1917

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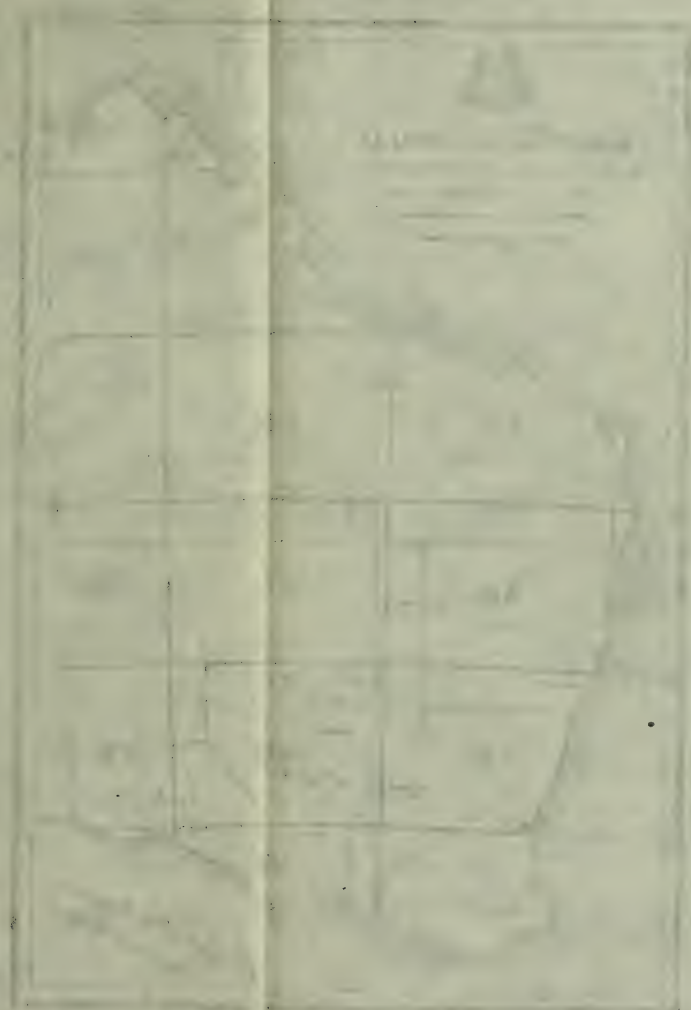
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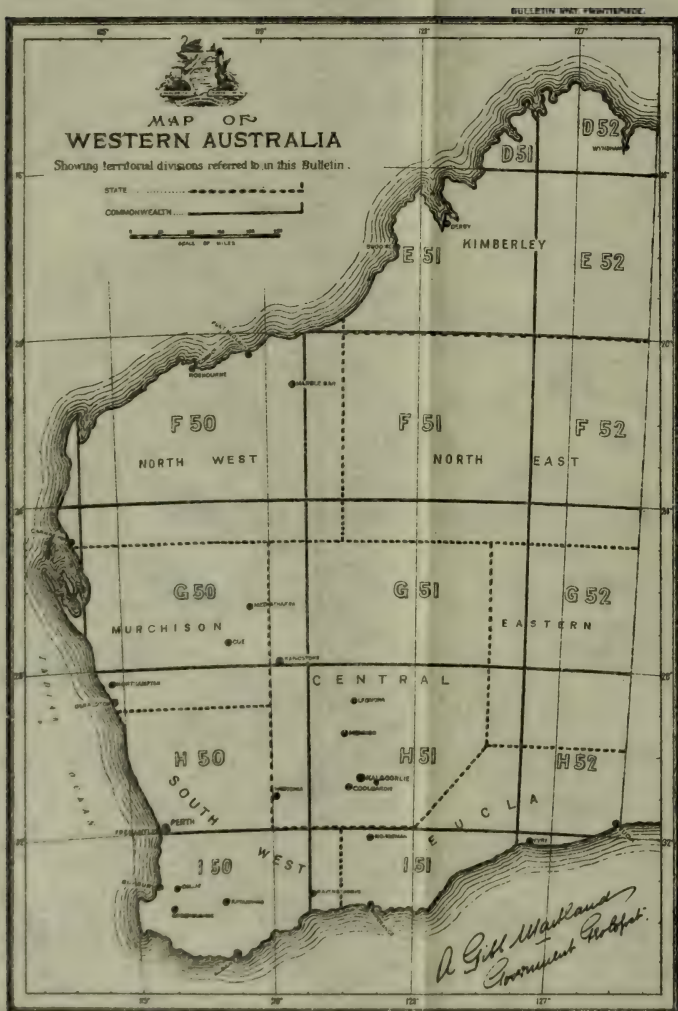
1916.

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067 N. 11.11





H J Pether, Government Lithographer, Perth, W.A.

PREFATORY NOTE.

During the ordinary course of the Geological Survey a number of analyses of rocks and natural waters have been made in the Laboratory by Mr. Simpson and the officers working under his direction. These have now been gathered together, and tabulated, and the form in which they have been arranged should render them of considerable value not only to Western Australian chemists and geologists, but also to others, for the figures have more than local significance.

A graphic method has been adopted by Mr. Simpson for presenting the quantitative petrographical data, on the Brögger system. These form Plates I. to X.

The analyses tabulated have been given the numbers [123], which serve to identify the rocks in the Geological Survey Collection, where, with one or two exceptions, the originals are preserved.

A number of analyses of Western Australian meteorites have been tabulated, and form Part II., whilst five tables of water analyses make up the third portion of the Bulletin.

A handwritten signature in dark ink, reading "A. G. Maitland". The signature is fluid and cursive, with a long, sweeping underline that extends to the right.

Government Geologist.

Geological Survey Office,
Perth, 9th May, 1916.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA.

LIST OF OFFICERS.

Government Geologist A. Gibb Maitland
(Director of the Survey.)

FIELD STAFF.

Assistant Government Geologist	..	..	..	..	H. P. Woodward
Assistant Geologist	..	..	..	..	T. Blatchford
Field Geologist	..	..	..	..	J. T. Jutson
Do.	..	..	..	..	H. W. B. Talbot
Do.	..	..	..	..	E. de C. Clarke
Do.	..	..	..	..	F. R. Feldtmann
Do.	..	..	..	..	C. S. Honman

LABORATORY STAFF :

Mineralogist and Chemist—E. S. Simpson.
Assistant Mineralogists and Chemists—
H. Bowley, D. G. Murray.

PETROLOGICAL STAFF :

Petrologist—R. A. Farquharson.

DRAFTING ROOM.

Draftsmen R. H. Irwin and C. B. Kidson.

OFFICE STAFF.

Clerk-in-Charge and Librarian	..	..	..	P. J. Atkins.
Clerk and Typist	..	..	..	J. D. Glover.
Messenger	..	..	..	R. Connolly.
General Assistant	..	..	..	B. S. Welsh.

LIST OF TABLES.

PART I.

ROCKS.

Table	Page
A.—Igneous Rocks, Silica over 70 per cent.	14
B.—Igneous Rocks, Silica, 60 to 70 per cent.	20
C.—Igneous Rocks, Silica, 50 to 60 per cent.	22
D.—Igneous Rocks, Silica, 40 to 50 per cent.	32
E.—Metasomatic Igneous Rocks, Silica, 64 to 80 per cent.	38
F.—Metasomatic Igneous Rocks, Silica, 47 to 64 per cent.	46
G.—Metasomatic Igneous Rocks, Silica, 30 to 47 per cent.	66
H.—Sedimentary Carbonate Rocks, Magnesia under 10 per cent.	80
I.—Sedimentary Carbonate Rocks, Magnesia over 10 per cent.	90
J.—Sedimentary Siliceous Rocks, Silica over 75 per cent.	96
K.—Sedimentary Siliceous Rocks, Silica under 75 per cent.	100
L.—Coals and Coal-shales	108
M.—Graphite Rocks	115
N.—Laterites	118
O.—Haematite-Quartz Rocks	124

PART II.

METEORITES.

P.—Meteorites	136
-----------------------	-----

PART III.

NATURAL WATERS.

Q.—Kimberley and North-West Divisions	146
R.—Murchison Division	148
S.—Central Division	156
T.—South-West Division	168
U.—Eucla Division	184

PLATES.

Plates 1 to 10.—Brögger-Hobbs' Diagrams of Rocks in Tables A, B, C, and D.

ABBREVIATIONS.

ANALYSTS AND PETROGRAPHERS—

H.B.	H. Bowley.
J.H.B.	John H. Brooking.
R.A.F.	R. A. Farquharson, M.A., M.Sc., F.G.S.
C.G.G.	Charles G. Gibson, B.E.
L.G.	Ludwig Glauert, F.G.S.
D.G.M.	D. G. Murray.
A.J.R.	A. J. Robertson, M.Sc.
E.S.S.	Edward S. Simpson, B.E., B.Sc., F.C.S.
B.R.S.	B. R. Synnott.
J.A.T.	J. Allen Thomson, M.A., D.Sc., F.G.S.
H.P.W.	H. P. Webb, A.R.S.M.
C.C.W.	Clive C. Williams.

TERRITORIAL DIVISIONS—

Kim.	Kimberley.
N.W.	North-West.
Mur.	Murchison.
Cen.	Central.
Eas.	Eastern.
S.W.	South-West.
Euc.	Eucla.

(H. 51), etc. Commonwealth Divisions as per accompanying map.

MISCELLANEOUS ABBREVIATIONS—

C.M.	Copper Mine.
G.M.	Gold Mine.
G.M.L.	Gold Mining Lease.
M.L.	Mineral Lease.
W.R.	Water Reserve, Water Right.
B. 43, etc.	Bulletin No. 43, etc., of the Geological Survey of Western Australia.
A.R., 1904, etc.	Annual Progress Report of the Geological Survey of Western Australia for the year 1904, etc.

Part I.

ROCKS.

PART I.

ANALYSES OF WESTERN AUSTRALIAN ROCKS.

The first section of this Bulletin is devoted to a tabulation of the numerous analyses of rocks, of various types and from all parts of the State, made in the Geological Survey Laboratory since its inception in 1897.

Two main types of analyses are now recognised in the Laboratory, viz.:—

Type A.—In this case the constituents determined are:—

SiO_2 , Al_2O_3 , Fe_2O_3 , FeO , MgO , CaO , Na_2O , K_2O , H_2O —,
 $\text{H}_2\text{O}+$, CO_2 , S , MnO , TiO_2 , P_2O_5 , Cr_2O_3 , V_2O_5 , BaO ,
and ZrO_2 .

Type B.—In this case V_2O_5 , BaO , and ZrO_2 are neglected and Cr_2O_3 only estimated in the case of ultrabasic rocks.

It will be seen that the majority of analyses tabulated below are of Type B. This is due to the fact that on the one hand only a small staff of analysts is at departmental disposal, whilst on the other hand a somewhat large field staff is constantly in need of analytical and determinative data. Analyses of Type A are therefore made but rarely, whilst from time to time analyses of an even less complete nature than Type B are carried out. It is to be noted in this connection that these analyses are for the most part made, not in order to form the basis of abstruse calculations or new methods of classification, but for purposes of rock determination and correlation within the particular area under review. For such purposes Type B analyses are almost always sufficiently detailed, though the figures for vanadium oxide are in some cases of diagnostic importance. This is particularly the case with that series of uralitised dolerites (diabases) which are so closely associated with many of the gold deposits in the Precambrian Complex. In this series the vanadium oxide almost invariably exceeds by a notable amount F. W. Clarke's average figure for that constituent, viz., 0.02 per cent. (1)

Less detailed analyses have only been made for rapid determinative purposes, as, for instance, to distinguish between microgranular soda and potash porphyries, or between talc-chlorite schists of peridotite or pyroxenite origin, and sericite-chlorite schists of dolerite origin.

(1) F. W. Clarke, "Data of Geochemistry," 2nd Edit., p. 32.

The methods of analysis are, for the most part, those of the United States Geological Survey, with some slight alterations which have been proved by experience to merit adoption. Of recent years all rock analyses have been made solely in vessels of quartz and platinum, using only chemicals of the highest purity obtainable in the world's markets, whose purity has been checked by ourselves in the case of each consignment.

The series of rocks tabulated in this section are not to be looked upon as quantitatively representative of the rocks of the whole area of Western Australia, though doubtless qualitatively so. For this reason any calculation of an average rock composition would be not only unjustifiable, but liable to result in entirely misleading interpretations. There would appear to be a tendency on the part of Field Geologists to take a greater interest in igneous rocks than in sedimentary ones, and in dyke rocks rather than rocks which form large masses, and finally in extraordinary rather than in ordinary types of rocks. This tendency explains, amongst other things, why, in the following pages, the immense areas of granite outcropping in this State are almost unrepresented. For example, to the east and south of Perth there is a batholith of granite, whose outcrop is practically bare over an area at least 300 miles long by 150 miles wide. This batholith is represented by two analyses only, viz., Nos. 798 from Bannister (p. 18) and 11221 from Mahogany Creek (p. 18). On the other hand the metasomatic dolerite of Kalgoorlie covering an area, perhaps, eight miles by two miles, is represented by no less than 28 analyses. The relative importance of the two areas from a mining point of view is, of course, also one of the prime reasons for this and other similar disproportions. The greater part of the energies of the Survey have since its inception been devoted to investigations of the gold deposits of the State, which form the basis of more than 90 per cent. of its mining industry, and it is only natural, therefore, that a large number of analyses should have been made in the Laboratory of the rocks which enclose the auriferous lodes, and at times, in the form of shear zones, actually constitute the lodes themselves, and of rocks which are suspected to have been concerned in the introduction of gold. Of the former class are the many forms of altered dolerites, such as amphibolites, propylites ⁽¹⁾, epidiorites, chlorite schists, etc. Of the latter class are quartz porphyries, and porphyrites, with other dyke rocks of more basic character.

Amongst the igneous rocks of the agricultural areas little chemical work has as yet been done, though it cannot be too widely recognised that such work would be of prime economic importance in connection with defining the areas of more fertile and less fertile land, and in determining on broad lines the direction which artificial fertilisation should take.

(1) Massive chloritised amphibolites and epidiorites.

The only classes of sedimentary rocks, in addition to coals, which up to the present have received much attention are the clays already of commercial importance, or likely soon to be, and the carbonate rocks of Paleozoic Age in the North-Western Division, and of Tertiary and Quaternary age in the South-West Division.

The system adopted in grouping the rock analyses may require some explanation. The tables having been drawn up primarily for reference purposes and not as a basis of present argument, they are arranged on a method which is thought to be most convenient for rapid reference. The main division has been into Igneous Rocks (not Metasomatic), Metasomatic Igneous Rocks, Sedimentary Rocks and Meteorites. In this scheme the rocks of igneous origin are thus divided into two main groups, those showing little or no evidence of metasomatism, and those showing definite evidence of such action, chiefly in the assimilation of carbonic acid, boric acid, water of constitution, sulphur or additional potash, ⁽¹⁾ from the emanations of more recent intrusions. Rocks have been included in the Igneous Rocks proper, which show foliation or other evidence of purely mechanical action, even when this is accompanied by internal molecular interchanges, as indicated for example by the formation of secondary albite, urallite, etc., provided there is no clear evidence of marked alteration in ultimate chemical composition from the introduction of extraneous matters such as those mentioned.

Keeping prominently in view the idea of ready reference, the subdivisions of the two first main groups have been made primarily on a basis of silica percentage, secondarily on a geographical basis. The silica percentages chosen as division points may at first sight appear arbitrary, but they have been chosen after considerable deliberation, and will be found, it is hoped, the best for the immediate purpose. That they are not devoid of theoretical significance will be seen in the case of the igneous rocks by comparison with the classification under the American Quantitative System.

The available information with regard to each rock has been so arranged as to be seen at one glance. Except when otherwise stated, the rocks must be assumed to show no effects of weathering visible to the naked eye. In the case of Group I., under the heading "Mode" will be found a list of the minerals actually present in the rocks in approximately their relative order of frequency. In the case of the unaltered igneous rocks I have added the "Norm," *i.e.*, the composition of the rock expressed in terms of certain standard

(1) J. A. Thomson postulates for many of the Kalgoorlie rocks an assimilation of albite from the emanations of more recent albite porphyries (ceratophyres). There is not, to my mind, the least evidence, qualitative or quantitative, in support of such a theory. Secondary albite is certainly present in these rocks, but no element of it has been introduced into the rock from outside sources. The albite is merely the unattacked residue, recrystallised *in situ*, of labradorite, the anorthite molecule of which has been completely decomposed at depth by carbonic acid, which acid has possibly, even probably, been an emanation from the ceratophyres. See J. A. T. "The Petrology of the Kalgoorlie Goldfield," Q. J. G. S., 69 621-77.

minerals, some of which do actually occur in the rock, others do not. The Norm enables the rock to be classified under the Quantitative System.

Five of the rocks proved to fall into sections of this System, for which no name has yet been suggested. Of these, No. 6880 (p. 20), a porphyry or ceratophyre from Cue, is a transition rock, II.4.2.5. close to I.4.2.5. (Mariposose), and as such not suitable as a basis for a new name. A somewhat similar case is No. 5646 (p. 30), hypersthenite, a local variation in a large intrusive dyke of norite (Auvergnose). This is a transition type close to Cookose, IV.1.1.1.1.(2). In a different category is No. 12782, tachylite from Poona. This falls in the middle of a previously unknown class, III. 4.4.3, but since it forms merely a thin (one inch) selvage on the flank of a large dyke, whose composition is not yet known, it would be inadvisable to found a new group name on the basis of its composition.

Quite otherwise must one consider the analyses of Nos. 11354, an amphibolite from Hell's Gates, East Murchison Goldfield, and 10418, a gabbro from Kalgoorlie. Both fall together in a new group, IV.1.1.2.2, the former being central in the group, the latter a transition type towards one unnamed group, IV. 1.1.3.2, and two named groups (auvergnose, ornose). These rocks, though uralitised, partly in one case and completely in the other, show no indications of having lost an appreciable amount of any original constituent, or of having gained an appreciable amount of any new material, other than water. Since they are similar types from widely separated localities, they form a fitting basis for a new group name. For this I suggest "Murchisonose," after the territorial division in which the more typical rock occurs.

In order to avoid as far as possible any perpetuation of or increase in the extraordinary confusion which still prevails in the older mineralogical system of rock nomenclature, as far as possible only well recognised group names have been employed under this system, type names such as "tonalite" being avoided. In the case of the more or less severely metasomatised igneous rocks of our Precambrian complex, suitable names are in many cases entirely lacking. In such cases titles as descriptive as possible of their origin and most pronounced alteration, such as "Carbonated Peridotite," have been employed.

Brögger-Hobbs Diagrams have been prepared of the unaltered igneous rocks.

Little comment is required upon the tables of analyses of Sedimentary Rocks. These are frequently incomplete, the reason being that they were rapid analyses made for purely technical purposes, such as to decide whether a given limestone could or could not be profitably burnt for use in agriculture.

Only typical analyses are included in the Table of Coals, many further analyses which have been made being merely repetitions on the same class of coal from the same pit.

The "Haematite-quartzites," rocks occurring in dyke or vein-like masses, and composed principally of chalcedony and haematite, with variable minor amounts of vitreous quartz and magnetite, are placed in a group by themselves, owing to the uncertainty which prevails with regard to their origin.

TABLE A.—IGNEOUS ROCKS—SILICA OVER 70 PER CENT.

G.S.M. No. ..	[5392.]	[3797.]	[13484.]	[13502.]	[13496.]
Rock	Ceratophyre.	Ceratophyre.	Porphyry.	Foliated Porphyry.	Soda-pegmatite.
Locality ..	Duffer's Crk.	Cue.	Niagara.	Niagara.	Niagara.
SiO ₂	72.77	74.86	84.11	77.95	78.58
Al ₂ O ₃	13.87	14.01	8.64	11.69	13.14
Fe ₂ O ₃	trace	1.12	trace	.95	.24
FeO	2.79	.36	.14	.34	.11
MnO	.22	.19	trace	<i>Nil</i>	<i>Nil</i>
MgO	.40	.42	.14	.07	.14
CaO	1.60	1.18	.19	1.22	.57
Na ₂ O	4.18	4.33	1.03	2.70	6.96
K ₂ O	2.81	3.07	5.93	4.42	.06
H ₂ O —	.02	.24	.03	.03	.08
H ₂ O + ...	.29	.13	.12	.29	.17
TiO ₂	.55	.13	.03	.17	.03
CO ₂	.24	.03	<i>Nil</i>	<i>Nil</i>	.16
P ₂ O ₅	..	.15	.13	Trace	Trace
FeS ₂	Trace	.04	<i>Nil</i>	<i>Nil</i>	.04
Total	99.74	100.26	100.49	99.83	100.28
Sp. gr.	2.69	2.63	2.60	2.63	2.61
Analyst ..	J.H.B.	E.S.S.	E.S.S.	A.J.R.	H.B.
Date	1904.	1902.	1914.	1915.	1915.

[5392.] Dyke. Outcrop. Duffer's Creek, near Marble Bar, N.W. Div. (F. 50). B. 40, pp. 7, 19.

[3797.] Dyke. Duke of York Extended G.M.L. 1287, 2½ miles N.E. of Township, Cue, Mur. Div. (G. 50) B. 29, 1, 65, 66. B. 29, 11, 50.

[13484.] Dyke. 4 miles W.N.W. of M.A. 42G, W. of Townsite, Niagara, Cen. Div. (H. 51).

[13502.] Dyke. W. of G.M.L. 3576, S.W. of Townsite, Niagara, Cen. Div. (H. 51).

[13496.] Dyke. North of G.M.L. 3685, S.W. of Townsite, Niagara, Cen. Div. (H. 51).

TABLE A.—*continued.*

G.S.M. No. ..	[5392.]	[3797.]	[13484.]	[13552.]	[13496.]
Locality ..	Duffer's Crk.	Cue.	Niagara.	Niagara.	Niagara.
Mode	Quartz Albite Oligoclase Biotite Muscovite Magnetite	Quartz Albite Orthoclase Oligoclase Biotite	Quartz Orthoclase Microcline Albite Oligoclase Muscovite Biotite Apatite	Quartz Orthoclase Biotite Chlorite Iron ore Kaolin Epidote ?	Albite Quartz Andesine ? Limonite Kaolin
Authority ..	E.S.S.	E.S.S.	E.S.S.	R.A.F.	E.S.S.
<i>Norm.</i>					
Quartz	31·36	35·04	54·90	42·54	36·54
Orthoclase ..	16·68	18·35	35·03	26·13	·36
Albite	35·63	36·68	8·91	23·06	58·69
Anorthite ..	8·06	5·00	·28	5·84	2·78
Corundum ..	1·02	1·63	·30	·31	·51
Hypersthene ..	5·62	1·00	·54	·20	·35
Magnetite ..	Trace	1·16	Trace	·58	·35
Hæmatite ..	..	·32	..	·55	..
Ilmenite ..	1·06	·24	·05	·33	·06
Pyrite	Trace	·04	<i>Nil</i>	<i>Nil</i>	·04
Apatite	..	·34	·30	Trace	Trace
Water, & CO ₂ ..	·31	·37	·15	·32	·25
Total	99·43	100·17	100·46	99·86	99·93
Classification ..	I.4.2.4 Lassenose	I.4.2.4 Lassenose	I.3.1.2 Magdeburgose.	I.3.2.3 Tehamose.	I.(3)4.1.5 Noyangose near West- phalose.

TABLE A.—*continued.*

G.S.M. No. ..	[13499.]	[5531.]	[12113.]	[1853.]	[11604.]
Rock	Pegmatite.	Soda-Granite.	Ceratophyre.	Australite.	Granite.
Locality ..	Niagara.	Coolgardie.	Kanowna. .. .	Kalgoorlie.	Southern Cross.
SiO ₂	74·75	70·40	71·40	71·65	75·83
Al ₂ O ₃	14·23	14·18	15·56	11·96	14·11
Fe ₂ O ₃	·19	·50	..	6·62	·49
FeO	·08	1·67	..	..	·12
MnO	<i>Nil</i>	·37	..	·16	Trace
MgO	·07	1·34	..	2·09	·25
CaO	·22	3·00	·29	3·03	·55
Na ₂ O	2·30	5·18	7·15	1·76	3·12
K ₂ O	8·46	1·88	<i>Nil</i>	2·40	5·32
H ₂ O —	·07	·06	..	..	·13
H ₂ O + ...	·03	·56	..	..	·41
TiO ₂	·01	·34	..	..	·08
CO ₂	·12	<i>Nil</i>	..	<i>Nil</i>	<i>Nil</i>
P ₂ O ₅	Trace	·14	..	..	·20
FeS ₂	·06	·22	..	..	Trace
Total	100·59	99·84	..	99·67	100·61
Sp. gr.	2·58	2·67	..	2·47	2·61
Analyst ..	H.B.	H.P.W.	H.B.	E.S.S.	A.J.R.
Date	1915.	1915.	1912.	1901.	1912.

[13499.] Dyke. N.W. of G.M.L. 3576, S.W. of Townsite, Niagara, Cen. Div. (H. 51).

[5531.] Batholith; 1,060 feet in Bore, Reserve 3647, Gnarlbine Road, 2 miles S.W. of Coolgardie, Cen. Div. (H. 51).

[12113.] Dyke. Red Hill, N.E. corner of Township, Kanowna, Cen. Div. (H. 51). B. 47, pp. 39, 71.

[1853.] Volcanic bomb (?). Found loose on surface. Kalgoorlie, Cen. Div. (H. 51).

[11604.] Batholith. West shore of Lake Koorkoordine, 13 chains S.E. of Hunt's Well, and E. of Bullfinch Road, Southern Cross, Cen. Div. (H. 50). B. 49, p. 56.

TABLE A.—*continued.*

G.S.M. No. ..	[13499.]	[5531.]	[12113.]	[1853.]	[11604.]
Locality ..	Niagara.	Coolgardie.	Kanowna.	Kalgoorlie.	Southern Cross.
Mode	Microcline Quartz Albite Oligoclase ? Muscovite Limonite	Oligoclase Quartz Microcline Biotite Hornblende Sphene Epidote Zoisite Ilmenite Zircon Apatite	Quartz Albite Chlorite Iron Ore	Glass Microlites	Quartz Microcline Orthoclase Oligoclase Biotite Muscovite Kaolin
Authority ..	E.S.S.	E.S.S.	R.A.F.	E.S.S.	R.A.F.
<i>Norm.</i>					
Quartz ..	28·44	24·84	..	38·22	36·72
Orthoclase ..	50·04	11·12	<i>Nil</i>	14·46	31·14
Albite ..	19·39	43·49	60·26	14·67	26·20
Anorthite ..	1·11	10·01	1·39	15·01	1·39
Corundum ..	·82	..	..	·90	2·75
Diopside ..	..	3·43	..	..	..
Hypersthene ..	·17	4·38	..	14·84	·60
Magnetite ..	·23	·70	..	·93	·11
Hæmatite ..	..	..	..	..	·43
Ilmenite ..	·02	·61	..	..	·15
Pyrite	·06	·22	..	..	Trace
Apatite ..	Trace	·34	..	..	·47
Water & CO ₂ ..	·22	·62	..	..	·54
Total	100·50	99·76	..	99·03	100·50
Classification ..	I.4.1.2 Omeose.	1 (II).4.2.4 Lassenose near Dacose.	.. Noyangose ?	II.3.3.3 Almerose.	I.3(4).1.3 Alaskose near (Liparose).

TABLE A.—*continued.*

G.S.M. No. ..	[11221.]	[798.]	[8553.]	[6034.]	[5455.]
Rock	Granite.	Granite.	Ceratophyre.	Granite.	Ceratophyre.
Locality ..	Mahogany Creek.	Bannister.	Ravensthorpe.	Norseman.	Norseman.
SiO ₂	73·36	72·00	71·01	78·35	77·81
Al ₂ O ₃	13·88	12·46	..	11·56	12·89
Fe ₂ O ₃	·84	·62	..	·61	Trace
FeO	·93	3·13	..	·90	·90
MnO	·15	..	..	·03	·08
MgO	·51	·27	..	·61	·88
CaO	1·69	1·41	..	·02	·05
Na ₂ O	3·22	3·47	8·50	2·86	4·18
K ₂ O	5·07	5·89	·52	3·97	2·39
H ₂ O —	·11	·15	..	·24	·09
H ₂ O + ...	·18	·26	..	·12	·44
TiO ₂	·04	·38	..	·18	·41
ZrO ₂	Trace	..	..	..	..
CO ₂	<i>Nil</i>	·03	..	·19	<i>Nil</i>
P ₂ O ₅	·07	..	..	..	..
FeS ₂	·05	..	..	·11	·21
BaO	·09	..	..	..	..
Total	100·19	100·07	..	99·75	100·33
Sp. gr.	2·66	2·62	2·68	2·64	2·68
Analyst ..	A.J.R.	C.C.W.	E.S.S.	J.H.B.	C.C.W.
Date	1911.	1901.	1908.	1905.	1905.

[11221.] Batholith. 10 feet below surface in Quarry 1 mile S.E. of Railway Station, Mahogany Creek, S.W. Div. (H. 50).

[798.] Batholith. Outerop, Kondening Katta Hill, Bannister, S.W. Div. (I. 50).

[8553.] Dyke alongside ore shoot, 400ft. level, Mt. Cattlin Copper Mine, Ravensthorpe, S.W. Div. (I. 51).

[6034.] Dyke East side of Lake Dundas, about 2 miles E. of Government Tank, Norseman, Euc. Div. (I. 51). B. 21, p. 28.

[5455.] Dyke, 350ft. level, Princess Royal Gold Mine, Princess Royal, near Norseman, Euc. Div. (I. 51).

TABLE A.—concluded.

G.S.M. No. ..	[11221.]	[798.]	[8553.]	[6034.]	[5455.]
Locality ..	Mahogany Creek	Bannister.	Ravens- thorpe.	Norseman.	Norseman.
Mode	Microcline Oligoclase Quartz Epidote Biotite Zoisite Hornblende Apatite	Felspar Quartz Biotite Chlorite Magnetite Epidote Kaolin	Quartz Albite Oligoclase Biotite Hornblende	Quartz Microcline Oligoclase Biotite Albite	Quartz Albite Muscovite Oligoclase
Authority ..	E.S.S.	R.A.F.	E.S.S.	E.S.S.	E.S.S.
<i>Norm.</i>					
Quartz ..	30·24	25·02	..	45·24	42·00
Orthoclase ..	30·02	35·03	2·78	23·35	14·46
Albite	27·25	29·34	71·79	24·10	35·63
Anorthite ..	8·34	·83	..	·28	·28
Corundum ..	..	..	..	2·45	3·16
Diopside ..	..	5·33	..	..	..
Hypersthene ..	2·62	2·41	..	2·42	3·39
Magnetite ..	1·16	·93	..	·93	..
Ilmenite ..	·08	·76	..	·30	·76
Pyrite	·05	..	..	·11	·21
Apatite ..	·16	..	..	..	..
Water & CO ₂ ..	·29	·44	..	·55	·53
Total	100·21	100·09	..	99·73	100·42
Classification ..	I.4.2.3 Toscanose.	I.4.1.3 Liparose.	.. Noyangose ?	I.3.1.3 Alaskose.	I.3.1.4 Taurose.

TABLE B.—IGNEOUS ROCKS—SILICA 60-70 PER CENT.

G.S.M. No.	[5397.]	[5426.]	[11202.]	[3796.]	[6880.]	[1/69.]	[8151.]
Rock ..	Soda Pegmatite	Grano- diorite.	Porphy- rite.	Grano- diorite.	Cerat- ophyre.	Grano- diorite.	Soda- granite.
Locality ..	Mool- yella.	Mosquito Creek.	Meeka- tharra.	Cue.	Cue.	Kookynie.	Raven- sthorpe.
SiO ₂ ..	68·36	63·08	67·18	63·62	66·43	65·02	68·11
Al ₂ O ₃ ..	18·74	15·10	17·34	14·38	16·22	16·07	15·77
Fe ₂ O ₃ ..	<i>Nil</i>	1·72	·79	3·29	·54	·86	·11
FeO ..	1·15	4·45	1·36	3·47	1·17	4·94	2·99
MnO ..	·45	·23	..	·28	<i>Nil</i>	·21	·16
MgO ..	·54	2·67	2·12	3·13	1·60	1·15	1·75
CaO ..	·39	2·83	1·43	5·43	5·88	3·77	3·79
Na ₂ O ..	10·22	4·37	9·74	4·40	6·35	4·76	4·58
K ₂ O ..	·07	3·86	Trace	1·20	·35	1·40	·76
H ₂ O — ..	<i>Nil</i>	·10	·40	·22	·20	·25	·11
H ₂ O + ..	·03	·58	·15	·06	·26	1·01	·86
TiO ₂ ..	·07	·68	..	·72	·68	·66	·74
CO ₂ ..	<i>Nil</i>	·11	..	<i>Nil</i>	<i>Nil</i>	·01	·21
P ₂ O ₅ ..	..	..	..	..	·40	·31	·28
FeS ₂ ..	<i>Nil</i>	·17	..	<i>Nil</i>	·04	·02	·17
Total ..	100·02	99·95	100·51	100·20	100·12	100·44	100·39
Sp. gr. ..	2·64	2·71	2·65	2·76	2·70	2·77	2·74
Analyst ..	C.C.W.	J.H.B.	H.B.	E.S.S.	C.C.W.	E.S.S.	J.H.B.
Date ..	1904.	1904.	1911.	1902.	1907.	1915.	1908.

[5397.] Dyke (Tin Lode), M.L. 2, Prospector's Creek, Moolyella, N.W. Div. (F. 50). B. 40, pp. 100, 102.

[5426.] Boss. W. of Parnell G.M., Mosquito Creek, N.W. Div. (F. 51). B. 40, p. 75.

[11202.] Dyke. 8 chains S.E. of S. peg of G.M.L. 263, "True Blue," Meekatharra, Mur. Div. (G. 50).

[3796.] Batholith, 160ft. level, Agamemnon Gold Mine, 2½ miles N.E. of Township, Cue, Mur. Div. (G. 50).

[6880.] Dyke. 20 chains W. of Township, Cue, Mur. Div. (G. 50).

[1/69.] Dyke or Batholith. Altona Gold Mine, Kookynie, Cen. Div. (H. 51).

[8151.] Batholith. Western Well on W.R. 7517, 2 miles S.E. of Township, Ravensthorpe, S.W. Div. (I. 51). Bull. 35, pp. 21, 23.

TABLE B.—*continued.*

G.S.M. No.	[5397.]	[5426.]	[11202.]	[3796.]	[6880.]	[1/69.]	[8151.]
Locality ..	Moolyella.	Mosquito Creek.	Meekatharra.	Cue.	Cue.	Kookynie.	Ravens- thorpe.
Mode ..	Albite Quartz Garnet Cassit- erite	Plagio- clase Ortho- clase Quartz Horn- blende Chlorite Biotite Sphene Apatite	Albite Quartz Amphi- bole Leu- coxene	Plagio- clase Quartz Biotite. Horn- blende Epidote Zoisite Apatite Muscovite	Oligo- clase Quartz Ortho- clase Augite Sphene	Plagio- clase Quartz Ortho- clase Biotite. Horn- blende Epidote Ilmenite Apatite Magnetite	Plagio- clase Quartz Biotite. Horn- blende Ilmenite Leuco- xene Apatite Pyrites
Authority ..	E.S.S.	E.S.S.	E.S.S.	E.S.S.	E.S.S.	E.S.S.	E.S.S.
<i>Norm.</i>							
Quartz ..	5·70	11·10	4·38	18·12	16·68	19·44	26·64
Orthoclase	·56	22·80	Trace	7·23	2·22	8·34	4·45
Albite ..	86·46	36·68	82·28	37·20	53·45	40·35	38·77
Anorthite ..	1·95	10·29	3·61	15·85	14·73	16·68	16·96
Corundum	1·02	..	..	..	..	·51	1·22
Diopside ..	..	3·22	2·91	8·90	9·42	..	..
Hypersthene	4·07	11·05	5·62	6·45	·10	10·59	8·76
Magnetite ..	..	2·55	1·16	4·87	·70	1·16	·23
Ilmenite ..	·15	1·37	..	1·37	1·37	1·22	1·37
Pyrite ..	..	·17	..	..	·04	·02	·17
Apatite ..	..	..	..	..	·95	·74	·67
Water, & CO ₂	·03	·79	·55	·28	·46	1·27	1·18
Total ..	99·94	100·02	100·51	100·27	100·12	100·32	100·42
Classification	I.5.1.5 Tuolum- nose	II.4(5).2. 4(3) Dacose, near Adamel- lose, etc.	I.5.1.5 Tuolum- nose	II.4.3.4 Tonalose	II(I).4.2.5 X near Maripo- sese	II(I).4.3.4 Tonalose, near Yellow- stonose	I(II).4.3.5 Amado- rose, near Placerose

TABLE C.—IGNEOUS ROCKS—SILICA 50-60 PER CENT.

G.S.M. No. ..	[3768.]	[3751.]	[3779.]	[5753.]	[7616.]
Rock	Dolerite.	Dolerite.	Basalt.	Porphyrite.	Dolerite.
Locality ..	Prince Regent R.	Synnott Creek.	Wyndham.	Mt. Edgar.	Secret Creek.
SiO ₂	50·70	50·98	52·58	58·16	51·93
Al ₂ O ₃	14·02	11·06	10·56	15·06	14·26
Fe ₂ O ₃	·90	5·72	7·10	4·37	2·49
FeO	12·76	10·67	9·12	2·66	10·76
MnO	·86	·65	·42	·25	·57
MgO	3·66	5·88	3·62	4·62	5·28
CaO	8·66	8·09	5·94	6·06	7·89
Na ₂ O	3·01	2·75	3·53	3·83	2·79
K ₂ O	1·37	2·11	2·80	2·91	·81
H ₂ O —	·20	·28	·56	·20	·09
H ₂ O + ...	1·35	1·73	1·33	1·00	1·13
TiO ₂	1·84	·70	2·62	·80	1·75
CO ₂	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
P ₂ O ₅	..	..	..	..	·31
FeS ₂	·20	·44	<i>Nil</i>	·09	·14
Total	99·50	101·06	100·18	100·01	100·20
Sp. gr.	2·95	2·94	2·87	2·78	3·00
Analyst ..	C.G.G.	C.C.W.	C.G.G.	C.C.W.	D.G.M.
Date	1902.	1902.	1902.	1904.	1907.

[3768.] Dyke. Gorge below Survey Station F.B. 52, N. of Mt. Shadforth, Upper Prince Regent River, Kim. Div. (D. 51).

[3751.] Flow (?). Survey Station F.B. 32, Synnott Creek, Charnley River, Kim. Div. (E. 51).

[3779.] Flow (?). Well at 6-mile, S.E. of Wyndham, Kim. Div. (D. 52).

[5753.] Dyke. Mt. Edgar, 27 miles E. of Marble Bar, N.W. Div. (F. 51). B. 40, p. 110.

[7616.] Flow or Sill. Secret Creek Gorge, S. of Soldier's Secret, Upper Ashburton River, N.W. Div. (F. 50). B. 33, p. 163; B. 35, pp. 51, 162.

TABLE C.—*continued.*

G.S.M. No. ..	[3768.]	[3751.]	[3779.]	[5753.]	[7616.]
Locality ..	Prince Regent R.	Synnott Creek.	Wyndham.	Mt. Edgar.	Secret Creek.
<i>Mode</i>	Augite Labradorite Chlorite Hornblende Quartz Ilmenite	Plagioclase Augite Chlorite Ilmenite	Plagioclase Augite Magnetite Ilmenite Serpentine	Plagioclase Orthoclase Hornblende Augite Chlorite Quartz Biotite Apatite	Labradorite Augite Quartz Orthoclase Ilmenite Hornblende Biotite Zoisite Epidote Chlorite
Authority ..	E.S.S.	E.S.S.	E.S.S.	E.S.S.	J.A.T.
<i>Norm.</i>					
Quartz	..	·48	5·10	7·86	4·20
Orthoclase ..	8·34	12·23	16·68	17·24	5·00
Albite	25·15	23·06	29·87	32·49	23·58
Anorthite ..	20·57	11·68	4·73	15·29	23·91
Diopside ..	19·16	23·63	20·31	11·51	11·11
Hypersthene ..	17·31	17·81	6·40	6·40	23·37
Olivine	2·36	..	..	..	..
Magnetite ..	1·39	8·35	10·21	6·50	3·71
Ilmenite ..	3·50	1·37	5·02	1·52	3·34
Pyrite	·20	·44	..	·09	·14
Apatite	..	..	..	..	·74
Water & CO ₂ ..	1·55	2·01	1·89	1·20	1·22
Total	99·53	101·06	100·21	100·10	100·32
Classification ..	III.5.3.4 Camptonose.	III.5.3(2).4 Camptonose, near Kilauose.	III.5.2.4(3) Kilauose, near Lamarose.	II.5.2(3).4 Akerose, near Andose.	III.5.3(4).4 Camptonose, near Auvergnose.

TABLE C.—*continued.*

G.S.M. No. ..	[6858.]	[3832.]	[6973.]	[11354.]	[6540.]
Rock	Epidiorite.	Norite.	Basalt.	Amphibolite.	Epidiorite.
Locality ..	Cue.	Cue.	Cue.	Hell's Gates.	Laverton.
SiO ₂	52·31	50·12	50·80	52·83	59·35
Al ₂ O ₃	14·64	14·90	11·63	4·35	15·83
Fe ₂ O ₃	3·09	1·66	2·91	·85	1·76
FeO	5·87	7·01	12·13	7·62	5·41
MnO	·29	·29	·09	·42	·33
MgO	8·90	10·00	4·61	16·47	4·58
CaO	9·32	13·04	8·31	14·24	6·43
Na ₂ O	2·57	1·95	2·41	·70	3·38
K ₂ O	·59	·08	1·56	·29	·90
H ₂ O —	·25	·13	·71	·17	·07
H ₂ O + ...	·88	·03	·93	·59	·83
TiO ₂	·41	·26	2·49	·41	·78
ZrO ₂	..	..	..	<i>Nil</i>	..
CO ₂	·05	·03	·29	·11	·06
P ₂ O ₅	·31	..	·68	·45	..
FeS ₂	·02	·13	·26	·04	·07
Cr ₂ O ₃	..	..	..	·20	..
V ₂ O ₃	..	..	..	·20	..
Total	99·50	99·63	99·81	99·74	99·78
Sp. gr.	3·00	3·02	2·96	3·11	2·86
Analyst ..	E.S.S.	E.S.S.	C.C.W.	H.B.	J.H.B.
Date	1906.	1902.	1907.	1911.	1906.

[6858.] Dyke (Uralitised quartz dolerite). Red, White, and Blue G.M.L. 745, ½ mile North of Racecourse, Cue, Mur. Div. (G. 50). B. 29, II., p. 50.

[3832.] Dyke. N. side of hill, W. of W.R. 7748, Cue, Mur. Div. (G. 50).

[6973.] Dyke. 100ft. below surface. Creme d'Or G.M.L. 389, East side of Railway Station, Day Dawn, Cue, Mur. Div. (G. 50). B. 29, II., p. 39.

[11354.] Dyke (?) (Uralitised dolerite or gabbro). Hill between Hell's Gates and Rocky Creek, Sandstone to Lawlers Road, Cen. Div. (G. 51). B. 43, p. 50.

[6540.] Dyke (Uralitised dolerite or gabbro). 2 miles W. of Ida H. G.M., Laverton, Cen. Div. (H. 51).

TABLE C.—*continued.*

G.S.M. No. ..	[6858.]	[3832.]	[6973.]	[11354.]	[6540.]
Locality ..	Cue.	Cue.	Cue.	Hell's Gates.	Laverton.
<i>Mode</i>	Hornblende Plagioclase Zoisite Quartz Leucoxene Epidote Chlorite Apatite	Plagioclase Augite Hypersthene Magnetite Ilmenite Pyrite	Augite Plagioclase Magnetite	Hornblende Augite Felspar Sphene Iron Ore	Zoisite Actinolite Albite Epidote Muscovite Leucoxene
Authority ..	E.S.S.	E.S.S.	E.S.S.	R.A.F.	E.S.S.
<i>Norm.</i>					
Quartz	3·06	..	5·16	·60	13·56
Orthoclase ..	3·34	·56	9·45	1·67	5·56
Albite	21·48	16·24	20·44	5·76	28·30
Anorthite ..	26·69	31·69	16·12	8·06	25·30
Diopside ..	14·06	26·66	17·20	47·82	5·44
Hypersthene ..	23·64	14·79	18·72	31·66	16·53
Olivine	..	6·30	..	..	..
Magnetite ..	4·41	2·55	4·18	1·16	2·55
Chromite ..	..	..	..	·29	..
Ilmenite ..	·76	·61	4·71	·76	1·52
Pyrite	·02	·13	·26	·04	·07
Apatite ..	·74	..	1·61	1·04	..
Water & CO ₂ ..	1·18	·19	1·93	·87	·96
Total	99·38	99·72	99·78	99·83	99·79
Classification ..	III.5.4.4(5) Auvergnose.	III.5.4.5 Auvergnose.	III.5.3.4 Camptonose.	IV.1 1.2.2 Murchis- sonose.	II.4.3.4 Tonalose.

TABLE C.—*continued.*

G.S.M. No. ..	[5088.]	[12466.]	[3208.]	[10426.]	[3222.]
Rock	Amphibolite.	Norite.	Porphyrite.	Amphibolite.	Amphibolite
Locality ..	Leonora.	Ora Banda.	Kalgoorlie.	Kalgoorlie.	Kalgoorlie.
SiO ₂	50·98	50·82	59·04	53·01	52·53
Al ₂ O ₃	17·09	13·98	15·74	15·23	13·42
Fe ₂ O ₃	·87	1·07	·60	2·79	·42
FeO	8·35	4·45	3·66	6·97	8·97
MnO	1·25	·38	·18	..	·63
MgO	4·70	14·33	4·48	6·95	9·17
CaO	9·70	13·04	7·59	10·02	9·63
Na ₂ O	4·09	·80	4·90	1·70	1·99
K ₂ O	·10	·20	1·47	·43	·72
H ₂ O —	·05	·14	·04	·10	·16
H ₂ O + ...	1·08	·20	·39	1·41	1·42
TiO ₂	·79	·10	·61	·96	·86
ZrO ₂	..	..	·03	..	<i>Nil</i>
CO ₂	<i>Nil</i>	<i>Nil</i>	·14	<i>Nil</i>	<i>Nil</i>
P ₂ O ₅	..	·08	·68	..	·20
FeS ₂	·19	·19	·15	..	·30
BaO	..	..	·05	..	<i>Nil</i>
Cr ₂ O ₃	..	·21	·02	..	·02
V ₂ O ₃	..	·04	·03	..	·04
Total	99·24	100·03	99·80	99·57	100·38
Sp. gr.	2·95	..	2·80	3·03	2·98
Analyst ..	C.C.W.	H.B.	E.S.S.	E.S.S.	J.H.B.
Date	1903.	1912.	1909.	1910.	1909.

[5088.] Dyke (Uralitised dolerite or gabbro). Tower Hill Gold Mine, Leonora, Cen. Div. (H. 51). B. 13, pp. 18-20.

[12466.] Dyke. W. of 52-mile post on Black Flag Road, S.W. of Ora Banda Township, Cen. Div. (H. 51). B. 54, pp. 35, 49, 112.

[3208.] Dyke. Abattoirs Reserve 7405, S.W. of Township, Boulder, Kalgorlie, Cen. Div. (H. 51). B. 42, pp. 37, 38.

[10426.] Dyke (?). West slope of Monument Hill, S. of Township, Boulder, Kalgoorlie, Cen. Div. (H. 51). B. 42, p. 37.

[3222.] Archaean flow (?). Commonwealth G.M.L. 3766, Mt. Hunt, Kalgoorlie, Cen. Div. (H. 51).

TABLE C.—*continued.*

G.S.M. No. ..	[5088.]	[12466.]	[3208.]	[10426.]	[3222.]
Locality ..	Leonora.	Ora Banda.	Kalgoorlie.	Kalgoorlie.	Kalgoorlie.
Mode	Hornblende Plagioclase Leucoxene Epidote Zoisite	Labradorite Hypersthene Diallage Chlorite Iron Ore	Plagioclase Amphibole Quartz Zoisite Chlorite Ilmenite Sphene Apatite Muscovite	Actinolite Zoisite Albite Epidote Leucoxene Chlorite	Amphibole Chlorite Zoisite Albite Muscovite Ilmenite
Authority ..	E.S.S.	R.A.F.	E.S.S.	E.S.S.	E.S.S.
<i>Norm.</i>					
Quartz ..	..	..	4·86	9·24	1·68
Orthoclase ..	·56	1·11	8·90	2·78	4·45
Albite ..	34·58	6·81	41·39	14·15	16·77
Anorthite ..	28·08	33·92	16·68	32·53	25·58
Diopside ..	16·70	24·12	13·50	13·90	17·03
Hypersthene ..	4·87	29·45	10·07	19·53	30·28
Olivine	10·32	1·81	..	..	..
Magnetite ..	1·39	1·62	·93	4·18	·70
Chromite ..	..	·31	..	..	..
Ilmenite ..	1·52	·15	1·22	1·82	1·67
Pyrite	·19	·19	·15	..	·30
Apatite ..	..	·19	1·62	..	·48
Water & CO ₂ ..	1·13	·34	·57	1·51	1·58
Total	99·34	100·02	99·89	99·64	100·52
Classification ..	II(III).5.3. (4)5 Beerbachose near Hessose, etc.	III.5.(4)5. 4(5) Ouenose near Auvergnose.	II.5.2(3).4 Akerose. near Andose.	(II)III.4.4.4 Koghose. near Bandose.	III.5.4.4 Auvergnose

TABLE C.—*continued.*

G.S.M. No. ..	[11777.]	[11455.]	[11463.]	[5631.]	[1419.]
Rock	Hornblende schist.	Hornblende schist.	Epidiorite.	Epidiorite.	Epidiorite.
Locality ..	Gibraltar.	Southern Cross.	Southern Cross.	Southern Cross.	Smith's Mill.
SiO ₂	50·71	53·37	52·50	52·70	50·96
Al ₂ O ₃	19·55	14·40	16·80	14·27	11·89
Fe ₂ O ₃	2·67	1·69	1·08	1·48	2·54
FeO	8·50	9·35	7·78	11·07	13·64
MnO	..	·26	..	·18	·34
MgO	4·77	7·54	7·32	6·39	6·26
CaO	9·56	10·69	10·06	8·23	9·94
Na ₂ O	2·58	1·90	2·25	3·15	2·68
K ₂ O	·28	·08	·85	·23	·29
H ₂ O —	·40	·12	·16	·24	·16
H ₂ O + ...	1·21	·50	1·01	·12	·05
TiO ₂	..	·62	..	·83	1·84
CO ₂	<i>Nil</i>	<i>Nil</i>	Trace	·15	<i>Nil</i>
P ₂ O ₅	..	·13	..	..	..
FeS ₂	..	·03	..	·49	..
Total	100·23	100·68	99·81	99·53	100·59
Sp. gr.	..	2·97	..	2·96	3·08
Analyst ..	H.B.	H.B.	E.S.S.	J.H.B.	E.S.S.
Date	1912.	1911.	1912.	1904.	1901.

[11777.] Dyke (?), possibly an altered sediment (tuff). G.M.L. 2295, Gibraltar, Cen. Div. (H. 51). B. 53, pp. 50, 71.

[11455.] Occurrence (?). Possibly an altered tuff. Road Cutting N. side of Lake Koorkoordine, Hopes Hill, Southern Cross, Cen. Div. (H. 50). B. 49, pp. 26, 84.

[11463.] Dyke (Uralitised dolerite). Near N.W. peg of G.M.L. 412, Southern Cross, Cen. Div. (H. 50). B. 49, pp. 31, 78.

[5631.] Dyke (Uralitised dolerite). Greenmount G.M., Greenmount, Southern Cross, Cen. Div. (H. 50). B. 17, p. 20.

[1419.] Dyke (Uralitised dolerite). 6ft. below surface in Railway Cutting W. of Smith's Mill (Glen Forrest), S.W. Div. (H. 50).

TABLE C.—*continued.*

G.S.M. No. ..	[11777.]	[11455.]	[11463.]	[5631.]	[1419.]
Locality ..	Gibraltar.	Southern Cross.	Southern Cross.	Southern Cross.	Smith's Mill.
Mode	Hornblende Felspar Quartz Iron Ore	Hornblende Felspar Quartz Sphene	Hornblende Felspar Biotite Sphene	Hornblende Plagioclase Quartz Ilmenite Epidote Calcite Apatite	Hornblende Labradorite Ilmenite Pyrites
Authority ..	R.A.F.	R.A.F.	R.A.F.	E.S.S.	E.S.S.
<i>Norm.</i>					
Quartz ..	2·58	5·88	1·26	1·74	·78
Orthoclase ..	1·67	·56	5·00	1·11	1·67
Albite	21·48	16·24	18·86	26·72	22·53
Anorthite ..	40·87	30·30	33·36	24·19	19·74
Diopside ..	5·53	18·05	13·63	13·82	24·81
Hypersthene ..	22·48	24·96	24·96	27·22	23·66
Magnetite ..	3·94	2·55	1·62	2·09	3·71
Ilmenite ..	..	1·22	..	1·52	3·50
Pyrite	..	·03	..	·49	..
Apatite ..	..	·31	..	..	..
Water & CO ₂ ..	1·61	·62	1·17	·51	·21
Total	100·16	100·72	99·86	99·41	100·61
Classification ..	II.5.4.5 Hessose.	III.(4)5.4.5 Auvergnose, near Koghose.	III.5.4.4 Auvergnose.	III.5.3(4).5 Ornose, near Auvergnose.	III.5.3(4).5 Ornose, near Auvergnose.

TABLE C.—*continued.*

G.S.M. No. 	[5581.]	[5438.]	[5646.]	Elder Exp. 12.
Rock 	Norite.	Norite.	Hypersthen- ite.	Norite.
Locality 	Norseman.	Norseman.	Norseman.	Cavanagh Range.
SiO ₂	50·55	52·72	55·27	51·55
Al ₂ O ₃	17·16	17·37	4·13	18·85
Fe ₂ O ₃	1·04	1·73	·45	·32
FeO 	3·40	5·53	7·17	6·77
MnO 	·19	·30	·03	·13
MgO 	9·97	7·42	28·36	7·09
CaO 	14·77	10·94	2·93	14·04
Na ₂ O 	1·62	2·93	·86	·63
K ₂ O 	·11	·65	·18	·08
H ₂ O — 	·12	·09	·04	·04
H ₂ O + ...	·36	·22	·30	·11
TiO ₂	·05	·61	·16	·53
CO ₂	<i>Nil</i>	·04	<i>Nil</i>	<i>Nil</i>
P ₂ O ₅	..	..	..	Trace
FeS ₂	·17	Trace	·17	<i>Nil</i>
Total 	99·51	100·55	100·05	100·14
Sp. gr. 	2·95	2·96	3·25	..
Analyst 	C.C.W.	J.H.B.	C.C.W.	G. J. Burrows
Date 	1904.	1904.	1904.	1910.

[5581.] Dyke. Cliff, W. side of Lake Cowan, first point S. of Causeway, Norseman, Euc. Div. (I. 51).

[5438.] Dyke, Surface, road about 35 chains S.W. of Trig. Station B. 22, Norseman, Euc. Div. (I. 51).

[5646.] Dyke (same as 5581, 5438). 55 chains E. of east end of Causeway, Norseman, Euc. Div. (I. 51).

[Elder Expedition 12.] Dyke. Cavanagh Range, Eastern Division (G. 52).

TABLE C.—*concluded.*

G.S.M. No. 	[5581.]	[5438.]	[5646.]	Elder Ex. 12.
Locality. 	Norseman.	Norseman.	Norseman.	Cavanagh Range.
Mode 	Plagioclase Hypersthene Augite Magnetite	Plagioclase Hypersthene Augite Magnetite Ilmenite	Hypersthene Plagioclase Augite	Plagioclase Hypersthene Augite Enstatite Hornblende Magnetite Ilmenite Olivine
Authority 	E.S.S.	E.S.S.	E.S.S.	J.A.T.
<i>Norm.</i>				
Quartz	..	..	..	6·24
Orthoclase	·56	3·89	1·11	·56
Albite	13·62	24·63	7·34	5·24
Anorthite	39·20	32·53	6·67	48·37
Diopside	27·15	17·70	6·15	17·43
Hypersthene	14·14	16·95	69·13	20·68
Olivine	2·54	·93	8·11	..
Magnetite	1·39	2·55	·70	·46
Ilmenite	·15	1·22	·30	1·06
Pyrite	·17	..	·17	..
Apatite	..	..	..	Traces
Water and CO ₂	·48	·35	·34	·15
Total	99·40	100·75	100·02	100·19
Classification	III.5.4.5 Auvergnose	(II)III.5.4. 4(5) Auvergnose near Hessose	IV.1.1.1.1(2) X near Cookose	II(III).5(4). 3(4).5 Beerbachose near Ornose, etc.

TABLE D.—IGNEOUS ROCKS—SILICA 40 to 50 PER CENT.

G.S.M. No. ..	[3771.]	[7728.]	[12782.]	[6870.]	[3823.]
Rock	Dolerite.	Dolerite.	Tachylite.	Epidiorite.	Amphibolite.
Locality ..	Mt. Lyell.	Irregularly Creek.	Poona.	Cue.	Cue.
SiO ₂	46·90	49·42	49·41	46·44	48·10
Al ₂ O ₃	14·12	14·95	11·64	20·22	15·41
Fe ₂ O ₃	·07	1·38	3·92	1·91	2·10
FeO	12·50	10·76	12·07	3·99	11·88
MnO	·29	·47	·38	·22	·05
MgO	6·96	6·16	4·37	9·19	6·58
CaO	10·92	9·85	7·92	15·18	12·73
Na ₂ O	2·85	2·70	1·02	1·05	2·11
K ₂ O	1·67	·72	1·25	·10	·14
H ₂ O —	·22	·09	·03	·18	·04
H ₂ O + ...	1·24	·77	4·85	·06	·33
TiO ₂	1·88	1·95	3·22	·42	·41
CO ₂	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	·24	·12
P ₂ O ₅	..	·55	·28	·36	..
FeS ₂	Trace	·26	·19	·20	·25
Total	99·62	100·03	100·55	99·76	100·25
Sp. gr.	3·02	3·01	3·02	3·03	3·11
Analyst	C.G.G.	H.B.	H.B.	J.H.B.	C.C.W.
Date	1902.	1907.	1913.	1902.	1902.

[3771.] Laccolite (?). 3 miles S.E. of Mt. Lyell, Glenelg River, Kim. Div. (D. 51).

[7728.] Sill or flow. Irregularly Creek, Upper Ashburton River, N.W. Div. (F. 50). B. 33, p. 169.

[12782.] Selvage to dolerite dyke. Creek, 10 chains N. of M.L. 12, Poona, Mur. Div. (G. 50).

[6870.] Dyke (Uralitised gabbro or dolerite). Polar Star G.M.L. 1277, 1½ miles W. of Township, Cue, Mur. Div. (G. 50).

[3823.] Flow (?) (Uralitised basalt ?). 9 chains S. of Princess Extd. G.M.L. 1232, Cue, Mur. Div. (G. 50).

TABLE D.—*continued.*

G.S.M. No. ..	[3771.]	[7728.]	[12782.]	[6870.]	[3823.]
Locality ..	Mt. Lyell.	Irregularly Creek.	Poona.	Cue.	Cue.
Mode	Augite Labradorite Olivine Magnetite Ilmenite Uralite Serpentine	Labradorite Augite Quartz Orthoclase Ilmenite Hornblende Biotite Chlorite Apatite Leucoxene	Glass Labradorite Magnetite Augite	Plagioclase Amphibole Zoisite Ilmenite Apatite	Hornblende Plagioclase Zoisite Leucoxene
Authority ..	E.S.S.	J.A.T.	E.S.S.	E.S.S.	E.S.S.
<i>Norm.</i>					
Quartz	..	..	12·48	..	..
Orthoclase ..	10·01	4·45	7·78	·56	·78
Albite	24·10	23·06	8·38	8·91	17·82
Anorthite ..	20·57	26·41	23·35	50·04	32·25
Diopside ..	1·61	15·65	11·60	18·35	25·64
Hypersthene ..	..	18·64	19·49	9·65	8·19
Olivine	27·20	3·86	..	7·17	11·08
Akermanite ..	10·96	..	..	..	..
Magnetite ..	·23	2·09	5·57	2·78	3·02
Ilmenite ..	3·65	3·65	6·08	·76	·76
Pyrite	..	·26	·19	·20	·25
Apatite	..	1·28	·67	·84	..
Water & CO ₂ ..	1·46	·86	4·88	·48	·49
Total	99·79	100·21	100·47	99·74	100·28
Classification ..	III.5.3.4 Camptonose.	III.5.(3)4.4 Auvergnose, near Camptonose.	III.4.4.3 X.	(II)III.5.5.5 Ouenose, near Corsase.	III.5.4.5 Camptonose.

TABLE D.—*continued.*

G.S.M. No. ..	[6874.]	[11350.]	[4417.]	[10418.]	[11008.]
Rock	Epidiorite.	Dolerite.	Amphibolite.	Gabbro.	Amphibolite.
Locality ..	Cue.	Mt. Holmes.	Yarri.	Kalgoorlie.	Kalgoorlie.
SiO ₂	46·27	49·27	46·55	48·72	47·12
Al ₂ O ₃	23·85	13·57	15·36	11·75	16·18
Fe ₂ O ₃	1·36	2·47	3·19	1·44	3·23
FeO	3·51	12·78	8·79	6·63	6·90
MnO	·32	·50	·45	·45	·45
MgO	6·65	4·26	9·80	10·92	7·23
CaO	14·89	8·51	10·56	16·45	13·80
Na ₂ O	1·52	2·44	1·50	·96	1·54
K ₂ O	·13	1·42	·33	·10	·11
H ₂ O —	·11	·22	·29	·06	·09
H ₂ O + ...	1·17	·55	1·31	1·28	1·92
TiO ₂	·49	2·13	1·12	1·04	·72
ZrO ₂	..	<i>Nil</i>	..	<i>Nil</i>	·01
CO ₂	·25	·10	Trace	<i>Nil</i>	<i>Nil</i>
P ₂ O ₅	·11	1·23	·06	·30	·15
FeS ₂	·08	·15	Trace	·24	·22
BaO	..	<i>Nil</i>	..	<i>Nil</i>	<i>Nil</i>
Cr ₂ O ₃	..	<i>Nil</i>	..	<i>Nil</i>	<i>Nil</i>
V ₂ O ₃	..	·09	..	·06	·01
Total	100·71	99·69	99·31	100·40	99·68
Sp. gr.	2·90	2·99	3·04	3·12	3·10
Analyst ..	J.H.B.	H.B.	E.S.S.	H.B.	H.B.
Date	1906.	1911.	1903.	1910.	1910.

[6874.] Dyke (Uralitised gabbro or dolerite). Homeward Bound G.M., 2 miles W.S.W. of Township, Cue, Mur. Div. (G. 50).

[11350.] Dyke. Near Trig. Station J.H.R. 196, Mt. Holmes, Sandstone-Lawlers Road, Cen. Div. (G. 51). B. 43, p. 46.

[4417.] Dyke (Uralitised dolerite). Yarri, Cen. Div. (H. 51).

[10418.] Dyke. ½ mile W. of old Boulder Abattoirs Reserve 7405, Boulder, Kalgoorlie, Cen. Div. (H. 51). B. 42, p. 35.

[11008.] Dyke (Uralitised quartz dolerite). Warden's Residence Reserve, Mt. Charlotte, Kalgoorlie, Cen. Div. (H. 51). B. 42, p. 32.

TABLE D.—*continued.*

G.S.M. No. ..	[6874.]	[11350.]	[4417.]	[10418.]	[11008.]
Locality ..	Cue.	Mt. Holmes.	Yarri.	Kalgoorlie.	Kalgoorlie.
<i>Mode</i>	Plagioclase Hornblende Chlorite Kaolin Calcite Leucoxene	Augite Felspar Hornblende Quartz Chlorite Apatite Iron Ores	Actinolite Plagioclase Zoisite Epidote Ilmenite Leucoxene	Diallage Plagioclase Magnetite Zoisite Ilmenite Leucoxene Chlorite	Hornblende Felspar Zoisite Leucoxene Quartz
Authority ..	E.S.S.	R.A.F.	E.S.S.	C.G.G.	E.S.S.
<i>Norm.</i>					
Quartz	..	2·40	..	..	..
Orthoclase ..	·56	8·34	1·67	·56	·56
Albite	12·58	20·96	12·58	8·38	13·10
Anorthite ..	57·82	21·96	34·47	27·52	36·97
Diopside ..	12·20	10·30	14·36	41·92	24·72
Hypersthene ..	4·36	24·28	21·92	11·87	15·54
Olivine	8·20	..	5·82	3·85	·17
Magnetite ..	2·09	3·48	4·64	2·09	4·64
Ilmenite ..	·91	3·95	2·13	1·98	1·37
Pyrite	·08	·15	..	·24	·22
Apatite ..	·27	2·92	·14	·70	·34
Water & CO ₂ ..	1·53	·87	1·60	1·34	2·01
Total	100·60	99·61	99·33	100·45	99·64
Classification ..	II.5.(4)5.5 Corsase, near Hessose.	III.5.3.4 Camptonose.	III.5.4.(4)5 Auvergnose.	IV.1.1.2(3).2 (III).5.(3)4.5 Murchisonose, near Auvergnose (Ornose).	III.5.4.5 Auvergnose.

TABLE D.—*continued.*

G.S.M. No. ..	[3231.]	[3306.]	[122.]	[11461.]	[6119.]	[5999.]
Rock	Epidiorite.	Epidiorite.	Amphibolite.	Epidiorite.	Dolerite.	Epidiorite.
Locality ..	Kalgoorlie.	Kalgoorlie.	Coolgardie.	Southern Cross.	Norseman.	Norseman.
SiO ₂	48·86	49·06	49·52	49·19	47·80	49·94
Al ₂ O ₃	13·47	14·30	15·66	18·96	14·30	19·45
Fe ₂ O ₃	2·18	3·14	3·23	·75	1·25	Trace
FeO	8·92	9·13	8·28	4·39	12·09	7·21
MnO	·90	·46	·31	..	·40	·63
MgO	7·65	6·05	9·40	10·00	7·40	9·64
CaO	12·19	10·86	10·61	14·69	10·17	11·23
Na ₂ O	2·58	2·38	2·26	·89	2·54	·90
K ₂ O	·19	·18	·23	<i>Nil</i>	·60	·07
H ₂ O —	·04	·10	·10	·08	·44	·06
H ₂ O + ...	1·51	1·71	·11	1·34	1·87	·73
TiO ₂	1·49	1·40	·89	..	1·23	·52
ZrO ₂	<i>Nil</i>	·02	..	..	..	..
CO ₂	<i>Nil</i>	<i>Nil</i>	·12	·14	·24	<i>Nil</i>
P ₂ O ₅	·11	·32	..	..	..	..
FeS ₂	·17	·56	·13	..	Trace	·05
BaO	·01	·03	..	..	..	..
Cr ₂ O ₃	·06	·02	..	..	..	..
V ₂ O ₃	·08	·25	..	..	..	..
Total	100·41	99·97	100·85	100·43	100·33	100·43
Sp. gr.	3·08	3·04	2·98	..	3·02	2·94
Analyst	E.S.S.	H.B.	C.C.W.	M.A.B.	E.S.S.	C.C.W.
Date	1909	1909	1902	1912	1905	1905

[3231.] Dyke (Uralitised gabbro). N. end of Star of Colac G.M.L. 2872, 1¼ miles S.W. of Explosives Reserve 6550, Boulder, Kalgoorlie, Cen. Div. (H. 51).

[3306.] Dyke (Uralitised gabbro or dolerite). S. end of Abattoirs Reserve 8814, Somerville, Kalgoorlie, Cen. Div. (H. 51).

[122.] Dyke.(?) Ophir G.M.L. 2447, Coolgardie, Cen. Div. (H. 51).

[11461.] Dyke (Uralitised gabbro, E.C.S.S.). 5 chains S.S.E. of S.W. peg of G.M.L. 1409, Southern Cross, Cen. Div. (H. 50). B. 49, pp. 27, 76.

[6119.] Dyke. Mt. Benson North G.M.L. 42, 1½ miles S. of Township, Norseman, Euc. Div. (I. 51).

[5999.] Dyke (Uralitised dolerite, J.A.T.). Sunbeam G.M.L. 157, West shore of Lake Kirk, Norseman, Euc. Div. (I. 51).

TABLE D.—concluded.

G.S.M. No. ..	[3231.]	[3306.]	[122.]	[11461.]	[6119.]	[5999.]
Locality ..	Kalgoorlie.	Kalgoorlie.	Coolgardie.	Southern Cross.	Norseman.	Norseman.
Mode	Hornblende Zoisite Albite Leucoxene Ilmenite Epidote	Hornblende Plagioclase Quartz Epidote Zoisite Ilmenite Leucoxene Chlorite	Hornblende Felspar Quartz Magnetite Biotite Sphene	Labradorite Hornblende Uralite Sphene Epidote	Plagioclase Augite Quartz Ilmenite Leucoxene Calcite Hornblende Chlorite	Hornblende Plagioclase Quartz Ilmenite Magnetite
Authority ..	E.S.S.	E.S.S.	R.A.F.	R.A.F.	E.S.S.	E.S.S.
<i>Norm.</i>						
Quartz	..	2·46	..	..	..	1·14
Orthoclase ..	1·11	1·11	1·11	..	3·34	·56
Albite	22·01	19·91	18·86	7·34	21·48	7·86
Anorthite ..	24·46	28·63	32·25	47·82	25·85	48·65
Diopside ..	28·81	19·20	16·41	19·95	20·29	5·88
Hpyersthenite ..	8·10	18·32	20·43	22·02	6·60	34·44
Olivine	7·70	..	4·88	·62	16·05	..
Magnetite ..	3·25	4·41	4·64	1·16	1·86	·23
Chromite ..	·10	·02	..	..	..	..
Ilmenite ..	2·89	2·74	1·67	..	2·28	·91
Pyrite	·17	·56	·13	..	..	·05
Apatite	·27	·77	..	..	..	..
Water & CO ₂ ..	1·55	1·81	·33	1·56	2·55	·79
Total	100·42	99·94	100·71	100·47	100·30	100·51
Classn. ..	III.5.4.5 Auvergnose	III.5.4.5 Auvergnose	III.5.4.5 Auvergnose	III.5.5.5 Ouenose	III.5.4.4(5) Auvergnose	III.5.5.5 Ouenose

**TABLE E.—METASOMATIC IGNEOUS ROCKS—SILICA 64·80
PER CENT.**

G.S.M. No. ..	[5404.]	[7618.]	[7562.]	[5063.]	[11193.]	[3976.]
Rock	Porphyry	Porphyry	Lava	Silicified Serpentine	Silicified rock	Porphyry
Locality ..	Bamboo Creek.	Dead Finish.	Bange- mall.	Yarra Yarra.	Meeka- tharra.	Cue.
SiO ₂	70·92	76·80	68·60	84·42	89·87	68·46
Al ₂ O ₃	12·77	13·91	10·18	1·43	3·32	12·25
Fe ₂ O ₃	Trace	<i>Nil</i>	1·34	7·17	·09	2·27
FeO	4·62	1·00	3·65	..	·50	3·20
MnO	·17	·26	·13	..	<i>Nil</i>	Trace
MgO	·33	·77	4·46	·52	·62	2·08
CaO	1·46	·24	1·59	·08	·28	2·63
Na ₂ O	3·32	1·16	·79	·24	·18	4·01
K ₂ O	3·92	3·04	2·76	·12	·20	2·05
H ₂ O—	·08	·07	·24	1·96	·28	·05
H ₂ O + ...	·54	1·88	2·38	4·08	1·96	·83
TiO ₂	·56	·14	1·56	..	1·31	·61
ZrO ₂	..	..	..	..	·02	..
CO ₂	·85	·08	1·32	<i>Nil</i>	·18	2·00
P ₂ O ₅	..	·33	·15	..	·03	..
FeS ₂	·10	·07	·06	<i>Nil</i>	·20	·15
BaO	..	..	..	..	·14	..
Cr ₂ O ₃	..	..	..	..	·12	..
V ₂ O ₃	..	..	..	..	<i>Nil</i>	..
Total	99·64	99·75	99·21	100·02	99·79	100·59
Sp. gr. ..	2·67	2·73	2·60	2·36	2·37	2·74
Analyst ..	E.S.S.	C.C.W.	D.G.M.	J.H.B.	H.B.	C.C.W.
Date	1904	1907	1907	1905	1911	1902

[5404.] Carbonated Porphyry. Flow. West side of Bamboo Creek, near Post Office, Bamboo Creek, N.W. Div. (F.51).

Components: Felspars, quartz, muscovite, chlorite, calcite (E.S.S.).

References: B. 40, pp. 49, 50.

[7618.] Sheared and sericitised Porphyry. Dyke. Gorge Creek near Reserve 1115, 5 miles S.E. of Mount Mortimer, N.W. Div. (F. 50).

Components: Quartz, muscovite, chlorite, iron ores, apatite, zircon (J.A.T.).

Reference: B. 33, p. 165.

[7562]. Carbonated lava (weathered). Flow. 1½ miles S. of Bangemall, N.W. Div. (G. 50).

Components: Quartz, chlorite, muscovite, albite, calcite, sphene (E.S.S.).

Reference: B. 33, p. 161.

[5063.] Silicified serpentine. Dyke or boss. Bulgaroo Tigers-Eye-Opal Find, Yarra Yarra Creek, Mur. Div. (G. 50).

Components: Opal, chloropal, iron hydrates (E.S.S.).

[11193.] Silicified rock. S.W. peg of Explosives Reserve 5326, Meekatharra, Mur. Div. (G. 50).

Components: Quartz, kaolin, sericite, leucoxene.

[3976.] Sheared and carbonated Porphyry (?). Dyke (?). Depth 2,030 feet in bore hole, G.M.L. 226, Day Dawn, Cue, Mur. Div. (G. 50).

Components: Quartz, sericite, albite, calcite, chlorite, biotite, iron ores (E.S.S.).

TABLE E.—*continued.*

G.S.M. No. ..	[1/122.]	[1/123.]	[13476.]	[5099.]	[4419.]	[4426.]
Rock	Green-stone Schist.	Green-stone Schist.	Porphyry.	Green-stone.	Gneiss.	Cerato-phyre.
Locality ..	Sand-stone.	Sand-stone.	Niagara.	Leonora.	Edjudina.	Edjudina.
SiO ₂	70·85	67·06	69·90	76·22	71·55	70·82
Al ₂ O ₃	15·36	13·60	15·20	12·55	14·82	15·56
Fe ₂ O ₃	4·03	·99*	1·27	3·52	·77	·51
FeO	·76	8·39	·42	<i>Nil</i>	1·58	1·73
MnO	..	..	Trace	Trace	·39	·13
MgO	·61	3·58	1·45	·70	1·07	·87
CaO	<i>Nil</i>	·13	1·63	·66	1·79	2·20
Na ₂ O	·20	·10	4·66	·08	4·98	5·57
K ₂ O	3·24	·14	2·27	2·01	1·56	1·94
H ₂ O —	·41	·72	·19	·32	·21	·05
H ₂ O + ...	3·83	4·47	1·33	3·72	·55	·27
TiO ₂	·80	..	·32	·86	·74	·35
CO ₂	<i>Nil</i>	<i>Nil</i>	1·33	<i>Nil</i>	<i>Nil</i>	·40
P ₂ O ₅	..	..	·12	..	..	..
FeS ₂	..	..	·15	<i>Nil</i>	·28	·20
Graphite ..	..	·52	..	..	..	..
Total	100·09	99·70	100·24	100·64	100·29	100·60
Sp. gr. ..	..	..	2·62	2·47	2·67	2·64
Analyst ..	H.B.	H.B.	A.J.R.	C.C.W.	C.C.W.	C.C.W.
Date	1913	1913	1914	1903	1903	1903

* Approximate.

[1/122.] Silicified and weathered chlorite schist, originally a dolerite lava or dyke. 200ft. level, Oroya Black Range Gold Mine, Sandstone, Cen. Div. (G. 50).

Components: Chalcedony, sericite, kaolin, iron ores (R.A.F.).
Reference: B. 62, p. 30.

[1/123.] Silicified chlorite schist with secondary graphite, of similar origin to [1/122].

400ft. level, Oroya Black Range G.M., Sandstone, Cen Div. (G. 50).

Components: Chalcedony, chlorite, graphite (E.S.S.).

Reference: B. 62, p. 30.

[13476.] Sericitised quartz porphyry. 4 miles N. of W. of M.A. 426, Kookynie, Cen. Div. (H. 51).

Components: Quartz, felspar, muscovite, calcite, chlorite, kaolin, brown iron ore (R.A.F.).

[5099.] Weathered amphibolite or chlorite schist. $\frac{1}{4}$ mile E.N.E. of Pride of Leonora (Ironstone) G.M.L. 618, Leonora, Cen. Div. (H. 51).

Components: Quartz, sericite, limonite, kaolin, ilmenite.

[4419.] Crushed Soda-Granite. Batholith. Wallaby G.M.L. 581, Yarri, Cen. Div. (H. 51).

Components: Quartz, albite, muscovite, sphene, pyrites, epidote, andalusite (E.S.S.).

[4426.] Carbonated quartz ceratophyre. Dyke. Trig. Station W. 19, Mount Catherine Range, Yerilla, Cen. Div. (H. 51).

Components: Quartz, albite, oligoclase, biotite, calcite (E.S.S.).

TABLE E.—*continued.*

G.S.M. No. ..	[11618.]	[2943.]	[12331B.]	[1989.]	[2335.]	[12490.]
Rock	Porphy-rite.	Porphy-rite.	Porphy-rite.	Cerato-phyre.	Cerato-phyre.	Cerato-phyre.
Locality ..	Mt. Monger.	Kal-goorlie.	Kal-goorlie.	Kal-goorlie.	Kal-goorlie.	Binduli.
SiO ₂	64·54	65·66	69·02	65·51	69·41	66·38
Al ₂ O ₃	12·65	13·55	15·92	18·12	15·87	16·41
Fe ₂ O ₃	2·33	1·63	·58	Trace	·24	1·52
FeO	2·12	1·56	1·90	2·39	1·58	·99
MnO	<i>Nil</i>	·23	·09	·05	·16	..
MgO	2·72	1·56	2·63	·38	1·14	1·01
CaO	4·92	5·46	·29	2·10	1·75	2·32
Na ₂ O	3·78	5·00	7·48	4·27	3·42	6·18
K ₂ O	2·12	1·96	<i>Nil</i>	3·28	2·44	2·28
H ₂ O—	·08	·10	·28	·07	·16	·09
H ₂ O+	1·83	·46	1·02	·46	·75	2·62
TiO ₂	·77	·50	·57	Traces	·20	..
ZrO ₂	..	·02	..	..	Trace	..
CO ₂	<i>Nil</i>	1·58	·14	2·41	2·52	·10
P ₂ O ₅	1·74	·54	·28	..	·55	..
FeS ₂	·13	·02	·11	·06	·07	..
BaO	..	·03	..	..	·08	..
Cr ₂ O ₃	..	·01	{ B ₂ O ₃ , Trace	..	<i>Nil</i>	..
V ₂ O ₃	..	·01		..	<i>Nil</i>	..
Total	99·73	99·88	100·31	99·10	100·34	99·90
Sp. gr.	..	2·75	..	2·72	2·72	2·65
Analyst	H.B.	E.S.S.	H.B.	C.G.G.	H.B.	A.J.R.
Date	1912	1909	1912	1902	1910	1912

[11618.] Altered porphyrite. Dyke. Majestic East G.M.L. 994E. Mount Monger, Cen. Div. (H. 31).

Components: Felspar, quartz, chlorite, epidote, muscovite, biotite, leucoxene, magnetite, sphene, apatite, kaolin (R.A.F.).

Reference: B. 53, p. 58.

[2943.] Carbonated Porphyrite. Dyke. Depth, 200 feet, Main Water Shaft, Reserve 9286, between Racecourse and Coolgardie Road, Kalgoorlie, Cen. Div. (H. 51).

Components: Quartz, felspars, chlorite, calcite, sericite, hornblende, biotite, apatite (E.S.S.).

Reference: Q.J.G.S. 49, 655-7.

[12331B.] Altered Porphyrite. Dyke. Hyman G.M.L. 4406E, Mullingar, Kalgoorlie, Cen. Div. (H. 51).

Components: Felspar, quartz, chlorite (scattered and pseudomorphs after hornblende), muscovite, iron ores (R.A.F.).

Reference: B. 51, p. 59.

[1980.] Carbonated Ceratophyre. Dyke. 150ft. level, Woodstock G.M.L. 1226E, $\frac{1}{2}$ mile N.W. of Ngumballa Townsite, Kalgoorlie, Cen. Div. (H. 51).

Components: Quartz, albite, orthoclase, sericite, calcite, chlorite (E.S.S.).

[2335.] Carbonated Ceratophyre. Dyke. 750ft. level, Union Jack G.M.L. 4421E, N.E. corner of Boulder Townsite, Kalgoorlie, Cen. Div. (H. 51).

Components: Quartz, albite, sericite, dolomite, chlorite, apatite, rutile, kaolin (E.S.S.).

[12490.] Altered Ceratophyre. Dyke. Well on Silver Train G.M.L. 3645E, N.W. of Railway Siding, Binduli, Cen. Div. (H. 51).

Components: Oligoclase, orthoclase, quartz, sericite, kaolin, chlorite, calcite (R.A.F.).

Reference: B. 56, p. 59.

TABLE E.—*concluded.*

G.S.M. No. ..	[12437.]	[12476.]	[1/59.]	[8139.]	[6111.]	[6029.]
Rock	Porphyry.	Cerato- pyhre.	Porphyry.	Soda- Granite.	Porphyry.	Porphyry .
Locality ..	Binduli.	Binduli.	Marda.	Ravens- thorpe.	Norse- man.	Norse- man.
SiO ₂	65·10	64·32	69·93	70·27	77·88	73·13
Al ₂ O ₃	16·99	18·46	13·92	16·11	12·05	12·21
Fe ₂ O ₃	1·09	5·24	1·04	·97	<i>Nil</i>	1·17
FeO	1·46	·19	2·80	1·22	·93	1·68
MnO	..	..	·26	·20	<i>Nil</i>	·67
MgO	1·05	·05	1·02	1·87	·62	·65
CaO	2·59	·09	2·21	1·76	Trace	2·81
Na ₂ O	2·60	9·01	3·87	4·64	3·16	3·52
K ₂ O	5·26	·32	3·18	·64	2·36	1·98
H ₂ O—	·09	·27	·04	·10	·06	·21
H ₂ O+	2·71	1·82	1·16	1·08	·69	·28
TiO ₂	·10	..	·28	·12	·04	·85
CO ₂	1·64	<i>Nil</i>	·16	·20	<i>Nil</i>	·88
P ₂ O ₅	..	..	·15	·12	..	..
FeS ₂	..	..	·02	·09	1·35	·20
Total	100·68	99·77	100·04	99·39	99·14	100·24
Sp. gr.	..	2·52	2·72	2·70	2·70	2·69
Analyst	H.B.	A.J.R.	E.S.S.	C.C.W.	C.C.W.	J.H.B.
Date	1912	1912	1915	1908	1905	1905

[12437.] Carbonated Porphyry. Dyke. 10 chains S.W. of W.R. 235E, N.W. of Railway Siding, Binduli, Cen. Div. (H. 51).

Components: Quartz, orthoclase, oligoclase-andesine, sericite, calcite, chlorite, kaolin, sphene, apatite, ilmenite (R.A.F.).

Reference: B. 56, p. 57.

[12476.] Altered Ceratophyre. Dyke. Open cut, 90 chains due W. of Railway Siding, Binduli, Cen. Div. (H. 51).

Components: Albite, quartz, kaolin, limonite (R.A.F.).

Reference: B. 56, p. 62.

[1/59.] Altered Porphyry. Dyke. Near North corner of Butcher Bird G.M.L. 1933, Marda, Cen. Div. (H. 50).

Components, Quartz, chlorite, orthoclase, plagioclase, glass, micro-spherulites, apatite, epidote, calcite, kaolin, iron ore, muscovite (R.A.F.).

[8139.] Altered Soda-granite. Batholith. Well, 25 chains S. of No. 2 Tank, W.R. 8358, Ravensthorpe, S.W. Div. (I. 51).

Components: Quartz, felspar, hornblende, chlorite, magnetite, calcite (E.S.S.).

[6111.] Altered Porphyry. Dyke. 270ft. level, Princess Royal G.M., Princess Royal, Norseman, Euc. Div. (I. 51).

Components: Quartz, muscovite, albite, chlorite, pyrites (E.S.S.).

[6029.] Altered Porphyry. Dyke. East side of Lake Dundas, about 2 miles E. of Government Tank, Norseman, Euc. Div. (I. 51).

Components: Felspars, quartz, biotite, ilmenite, muscovite, calcite (E.S.S.).

TABLE F.—METASOMATIC IGNEOUS ROCKS—SILICA 47 TO 64 PER CENT.

G.S.M. No. ..	[3760.]	[3776.]	[3753.]	[3749.]	[5794.]	[5773.]
Rock	Epidosite.	Dolerite.	Dolerite.	Epidiorite.	Dolerite.	Dolerite.
Locality ..	Synnott Creek.	Monger Creek.	Isdell River.	Charnley River.	Nullagine.	Warra-woona.
SiO ₂	55·43	51·04	54·44	51·40	54·92	50·48
Al ₂ O ₃	12·83	13·60	7·72	16·38	14·27	23·18
Fe ₂ O ₃	9·87	2·08	8·22	1·26	1·28	3·07
FeO	2·47	8·40	11·20	12·78	5·25	8·86
MnO	·36	·34	·22	Trace	Trace	..
MgO	·59	7·94	4·00	2·30	10·32	·64
CaO	16·09	5·68	6·68	7·32	6·42	7·47
Na ₂ O	·37	4·30	3·14	3·14	2·50	2·17
K ₂ O	·22	1·83	1·91	1·72	·64	·83
H ₂ O—	·15	·36	·20	·12	·12	·10
H ₂ O+	·32	2·64	2·01	1·99	2·96	1·71
TiO ₂	·34	1·36	1·48	1·06	·90	·38
CO ₂	·41	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	·38	·55
FeS ₂	·16	<i>Nil</i>	·16	<i>Nil</i>	·22	·30
Total	99·61	99·57	100·38	99·47	100·18	99·74
Sp. gr. ..	3·12	2·81	2·86	2·94	2·82	3·00
Analyst ..	A.J.R.	C.G.G.	C.G.G.	C.G.G.	C.C.W.	C.G.G.
Date	1911	1902	1902	1902	1905	1904

[3760.] Epidosite, altered Dolerite. Portion of Flow (?). Camp F.B. 32, Synnott Creek, Lower Charnley River, Kim. Div. (E. 51).

Components: Epidote, zoisite, glaucophane (?), quartz, ilmenite, leucoxene, pyrites (R.A.F.).

[3776.] Altered Dolerite. 3 miles N. of F.B. 79, Napier Broome Bay, Kim. Div. (D. 52).

Components: Plagioclase, augite, serpentine, sphene (E.S.S.).

[3753.] Altered Dolerite. Isdell River, Kim. Div. (E. 51).

Components: Felspar, augite, chlorite, quartz, ilmenite, leucoxene (E.S.S.).

[3749.] Epidiorite, uralitised Dolerite. 1 mile N.W. of junction of Maurice Creek and Charnley River, Kim. Div. (E. 51).

Components: Hornblende, felspar, chlorite, olivine, serpentine, magnetite (E.S.S.).

[5794.] Altered Dolerite. Dyke. N. side of Nullagine River, near One-mile Creek, Nullagine, N.W. Div. (F. 51).

Components: Plagioclase, augite, actinolite, quartz, biotite, ilmenite, zoisite, calcite (E.S.S.).

Reference: B. 40, pp. 133-4.

[5773]. Altered Dolerite. Dyke. Warrawoona, N.W. Div. (F. 50).

Components: Plagioclase, augite, actinolite, epidote, zoisite, ilmenite, calcite (E.S.S.).

Reference: B. 40, p. 162.

TABLE F—*continued.*

G.S.M. No. ..	[5780.]	[5793.]	[5779.]	[5405.]	[5384.]	[5377.]
Rock	Propylite.	Epidio-rite.	Chlorite Schist.	Propylite.	Altered Lava.	Epidio-rite.
Locality ..	Warra-woona.	Warra-woona.	Warra-woona.	Bamboo Creek.	North Pole.	Box Soak.
SiO ₂	48·54	50·20	55·00	53·85	54·41	50·21
Al ₂ O ₃	13·67	17·95	24·30	14·00	12·80	15·45
Fe ₂ O ₃	2·13	9·49	3·93	·36	·16	·38
FeO	10·04	4·20	7·53	8·12	10·35	6·47
MnO	Trace	·37	Trace	·87	·09	1·40
MgO	4·54	2·26	2·30	4·51	5·72	7·27
CaO	6·46	7·76	·18	6·43	5·21	14·34
Na ₂ O	3·58	1·01	2·43	3·14	3·02	1·72
K ₂ O	·04	·14	Trace	·60	·02	·47
H ₂ O—	·04	·10	·27	·06	·15	·03
H ₂ O+	2·74	3·04	3·14	2·94	3·42	2·07
TiO ₂	1·12	1·42	traces	·55	·78	·25
CO ₂	7·14	1·12	·98	4·37	3·58	·11
FeS ₂	·26	·30	Trace	..	..	·15
Total	100·30	99·36	100·06	99·80	99·71	100·32
Sp. gr. ..	2·84	3·07	2·62	2·79	2·77	3·04
Analyst ..	C.C.W.	B.R.S.	C.G.G.	C.C.W.	C.C.W.	C.C.W.
Date	1904	1905	1904	1904	1904	1904

[5780.] Propylite, altered Dolerite. Dyke (?). Horseshoe Shaft, Bow Bells G.M.L. 505, Warrawoona, N.W. Div. (F. 50).

Components: Plagioclase, chlorite, quartz, dolomite, zoisite, actinolite, ilmenite, leucoxene, epidote (E.S.S.).

Reference: B. 40, p. 164.

[5793.] Epidiorite, uralitised Dolerite. Dyke (?). Warrawoona, N.W. Div. (F. 50).

Components: Actinolite, plagioclase, quartz, ilmenite, magnetite, calcite, epidote, zoisite, chlorite (E.S.S.).

[5779.] Chlorite Schist, sheared and chloritised Dolerite (?). Main Shaft, Gauntlet G.M.L. 483, Warrawoona, N.W. Div. (F. 50).

Components: Chlorite, quartz, albite, dolomite, leucoxene (E.S.S.).

Reference: B. 40, p. 160.

[5405.] Propylite, chloritised Dolerite (?). Dyke (?). Bulletin G.M.L. 161, Bamboo, N.W. Div. (F. 51).

Components: Plagioclase, calcite, chlorite, zoisite, leucoxene (E.S.S.).

[5384.] Altered Lava, Amygdaloidal Basalt (?). Flow. Shaw River, 6 miles above North Pole, N.W. Div. (F. 50).

Components: Felspar, chlorite, calcite, glass, iron ore, quartz (R.A.F.).

[5377.] Epidiorite, uralitised Dolerite. Dyke. Hills near Box Soak, 30 miles S.E. of Port Hedland, N.W. Div. (F. 50).

Components: Plagioclase, hornblende, zoisite, sphene (E.S.S.).

TABLE F.—*continued.*

G.S.M. No. ..	[6484.]	[6481.]	[10647.]	[10671.]	[10620.]	[6439.]
Rock	Epidio-rite.	Chlorite Schist.	Alt. Porphyrite.	Porphyrite.?	Basalt.	Andesite.
Locality ..	Station Peak.	Station Peak.	Sherlock River.	Lockyer's Gap.	Peawah.	Mount Anketell.
SiO ₂	52·50	49·03	52·10	51·23	48·05	53·11
Al ₂ O ₃	14·93	14·29	16·35	9·89	13·82	15·55
Fe ₂ O ₃	2·75	1·16	1·18	1·07	·73	1·26
FeO	7·87	6·86	7·91	9·07	15·43	7·17
MnO	·27	·33	·35	·41	·97	·59
MgO	7·22	7·39	3·71	13·37	3·91	6·50
CaO	6·73	7·85	7·35	6·43	5·78	8·93
Na ₂ O	2·04	·30	3·30	2·16	1·14	3·03
K ₂ O	·61	2·63	·68	·84	·30	·28
H ₂ O—	·06	·14	·12	·25	·08	·04
H ₂ O+	2·86	3·82	2·36	3·52	4·24	3·12
TiO ₂	·78	·36	2·08	·54	1·14	·40
CO ₂	1·12	6·03	2·49	·20	4·42	·32
P ₂ O ₅	..	..	·45	·53	·27	..
FeS ₂	·13	·09	·17	·13	·32	·07
Total	99·87	100·18	100·60	99·64	100·60	100·37
Sp. gr.	2·89	2·80	2·85	2·88	2·89	2·91
Analyst	C.C.W.	C.C.W.	H.B.	H.B.	H.B.	C.C.W.
Date	1906	1906	1910	1910	1910	1905

[6484.] Epidiorite, uralitised quartz Dolerite. Dyke. Northern Dyke, Main Ridge, Station Peak, N.W. Div. (F. 50).

Components: Felspar, chlorite, amphiboles, epidote, calcite, quartz, leucoxene, ilmenite, sillimanite (J.A.T.).

Reference: B. 33, p. 156.

[6481.] Chlorite schist, foliated and carbonated quartz dolerite. Crushed zone in dyke. Northern dyke, main ridge, Station Peak, N.W. Div. (F. 50).

Components: Chlorite, calcite, muscovite, quartz, albite, leucoxene, apatite (J.A.T.).

Reference: B. 33, pp. 107, 154.

[10647.] Carbonated Porphyrite. Dyke. Head of East Branch, Sherlock River, N.W. Div. (F. 50).

Components: Zoisite, chlorite, albite, hornblende, epidote, calcite, ilmenite, leucoxene, sericite, magnetite (L.G.).

Reference: B. 41, p. 31.

[10671.] Altered Porphyrite (?). Lockyer's Gap, Harding River, N.W. Div. (F. 50).

Components: Albite, epidote, zoisite, chlorite, quartz (L.G.).

Reference: B. 41, p. 36.

[10620.] Altered vesicular Basalt. Flow. Hill N.W. of Peawah Hill, Peawah, N.W. Div. (F. 50).

Components: Felspar, chlorite, calcite, quartz, iron ores, apatite (L.G.).

Reference: B. 41, p. 28.

[6439.] Altered Andesite. Flow. Summit of Mount Anketell, N.W. of Roebourne, N.W. Div. (F. 50).

Components: Plagioclase, augite, olivine, serpentine, epidote, quartz, ilmenite (L.G.).

Reference: B. 33, p. 148.

TABLE F.—*continued.*

G.S.M. No. ..	[Fa.]	[11579.]	[3847.]	[6885.]	[8912.]	[13629.]
Rock	Talc Schist.	Talc Rock.	Epidio-rite.	Segrega- tion or Inclusion.	Graphitic Schist.	Graphitic Schist.
Locality ..	Mt. Taylor.	Meeka-tharra.	Cue.	Cue.	Day Dawn.	Sand-stone.
SiO ₂	61·00	57·37	48·09	57·25	62·62	53·93
Al ₂ O ₃	·80	1·14	19·77	15·15	18·78	20·41
Fe ₂ O ₃	..	·51	1·43	·84	1·00 ⁽²⁾	·57 ⁽²⁾
FeO	6·14	6·52	6·99	3·51	2·62	11·03
MnO	·20	..	·29	·23	·16	..
MgO	27·88	26·98	7·56	2·88	3·09	2·90
CaO	<i>Nil</i>	·53	11·30	6·49	·82	1·57
Na ₂ O	..	·25	2·17	2·19	2·30	·28
K ₂ O	..	<i>Nil</i>	·07	2·90	3·30	·88
H ₂ O —	·12	·87	·17	·12	·13	·58
H ₂ O + ...	4·72	6·17 ⁽¹⁾	2·05	1·05	2·07	5·48
TiO ₂	..	..	·12	·52	·16	..
CO ₂	<i>Nil</i>	Traces	·12	5·21	<i>Nil</i>	1·24
P ₂ O ₅	..	..	..	·23	·29	..
FeS ₂	..	..	·11	·95	1·22	..
Carbon	..	..	..	..	1·60	·68
Total	100·86	100·34	100·24	99·52	100·22	99·55
Sp. gr.	..	2·82	2·98	2·70	2·76	..
Analyst	E.S.S.	A.J.R.	C.C.W.	C.C.W.	E.S.S.	H.B.
Date	1911	1911	1902	1907	1910	1913

(1) Includes traces of CO₂.

(2) Approximate only. Owing to the presence of finely-divided graphite the exact proportions of Fe₂O₃ and FeO were not determinable.

[(Fa).] Tale schist, altered Peridotite. Dyke or boss.
Mt. Taylor, Mur. Div. (G. 50).

Components: Tale, chlorite (E.S.S.).

[11579.] Tale Rock, altered Peridotite. Dyke.

Ingliston Extended G.M., Meekatharra, Mur. Div. (G. 50).

Components: Tale, chlorite, carbonate.

Reference: B. 43, p. 73.

[3847.] Gneissic Epidiorite, altered Gabbro or Dolerite. Dyke.

Well on W.R. 7748, S.W. corner of Township, Cue, Mur. Div.
(G. 50).

Components: Hornblende, uralitic hornblende, chlorite, quartz,
kaolin, zoisite, labradorite, albite, leucoxene (R.A.F.).

[6885.] Carbonated Segregation or Inclusion in Granodiorite.

Deep shaft, Countess G.M.L. 1066, 1¼ N.E. of Township,
Cue, Mur. Div. (G. 50).

Components: Sericite, quartz, calcite, chlorite, albite, ilmenite,
leucoxene, pyrites (E.S.S.).

[8912.] Graphitic schist, crush zone in altered Dolerite (?).

1,520ft. level, Great Fingall G.M., Day Dawn, Cue, Mur. Div.
(G. 50).

Components: Sericite, chlorite, albite, quartz, graphite, pyrites.

Reference: A.R., 1909, pp. 24, 25.

[13629.] Graphitic schist, crush zone in altered Dolerite.

250ft. level, Black Range West G.M., Sandstone, Cen. Div.
(G. 50).

Components: Chlorite, sericite, calcite, graphite, quartz.

Reference: B. 62, pp. 30, 47.

TABLE F—*continued.*

G.S.M. No. ..	[13629A.]	[4425.]	[5·86.]	[5·89.]	[13489.]	[12464.]
Rock	Green-stone Schist.	Amphibolite.	Carbonated Amphibolite.	Talc Chlorite Schist.	Gneiss.	Epidiorite.
Locality ..	Sandstone.	Malcolm.	Leonora.	Leonora.	Niagara.	Ora Banda.
SiO ₂	57·17	48·06	53·09	47·70	60·52	47·27
Al ₂ O ₃	18·67	16·21	16·03	9·99	17·61	17·36
Fe ₂ O ₃	?	·89	4·36	1·60	1·21	1·50
FeO	9·95	10·37	1·73	7·33	4·33	3·85
MnO	..	·59	..	1·38	·10	·35
MgO	3·41	6·67	3·36	22·49	3·57	8·68
CaO	·18	11·37	5·16	·69	7·03	16·93
Na ₂ O	2·16	2·50	8·09	·43	3·25	·54
K ₂ O	2·08	·27	·03	·38	1·22	·06
H ₂ O—	·97	·10	·05	·21	·04	·16
H ₂ O+	3·58	·59	·56	6·62	1·05	3·20
TiO ₂	..	·90	·98	·52	·46	·41
CO ₂	<i>Nil</i>	1·03	6·33	1·35	<i>Nil</i>	<i>Nil</i>
P ₂ O ₅	..	..	..	..	·11	·29
FeS ₂	..	·34	·26	..	Trace	·07
Carbon	1·29	..	..	..	..	..
Total	99·46	99·89	100·03	100·69	100·50	100·67
Sp. gr.	..	3·04	2·73	2·80	2·85	..
Analyst	H.B.	J.H.B.	C.C.W.	C.C.W.	A.J.R.	H.B.
Date	1913	1903	1903	1904	1914	1912

[13629A.] Graphitic schist, crush zone in altered Dolerite. 200ft. level, Black Range West G.M., Sandstone, Cen. Div. (G. 50).

Components: Chlorite, sericite, graphite, quartz (R.A.F.).

Reference: B. 62, pp. 30, 47.

[4425.] Amphibolite, uraltised dolerite. Dyke.

Malcolm, Cen. Div. (H. 51).

Components: Amphibole, plagioclase, ilmenite, magnetite, quartz, calcite (E.S.S.).

[5086.] Carbonated amphibolite, altered dolerite (?). Dyke.

Outerop $\frac{1}{2}$ mile E. of Mt. George, Leonora, Cen. Div. (H. 51).

Components: Albite, chlorite, dolomite, ilmenite, quartz, rutile, kaolin, apatite (R.A.F.).

[5089.] Tale-chlorite schist, altered peridotite or pyroxenite. Dyke.

Tower Hill G.M.L. 4387, Leonora, Cen. Div. (H. 51).

Components: Talc, chlorite, dolomite, rutile, quartz, albite (R.A.F.).

[13489.] Biotite-hornblende Gneiss, altered Granodiorite. Batholith.

G.M.L. 503G, 3 miles West of Niagara, Cen. Div. (H. 51).

Components: Felspars, biotite, quartz, chlorite, hornblende, epidote, zoisite (R.A.F.).

[12464.] Epidiorite, altered dolerite or gabbro. Dyke.

High ridge West of Sink to Rise G.M.L. 1587, N. of Townsite, Ora Banda, Cen. Div. (H. 51).

Components: Hornblende, zoisite, leucoxene, sphene, chlorite, epidote (R.A.F.).

Reference: B. 54, p. 113.

TABLE F.—*continued*

G.S.M. No. ..	[12465.]	[12410.]	[12662.]	[12985.]	[12663.]	[11636.]
Rock	Epidiorite	Porphyrite	Porphyrite.	Porphyrite.	Porphyrite.	Alt. Porphyrite.
Locality ..	Ora Banda.	Ora Banda.	Ora Banda.	Ora Banda.	Ora Banda.	Mt. Monger.
SiO ₂	49·71	47·46	47·76	49·20	43·31 ⁽¹⁾	56·96
Al ₂ O ₃	13·17	15·10	15·88	16·12	17·85	15·19
Fe ₂ O ₃	2·18	4·09	2·64	2·31	3·68	1·13
FeO	10·04	9·99	7·70	2·90	5·93	4·17
MnO	·32	·32	·45	·25	·41	·68
MgO	7·52	5·46	4·13	3·72	3·72	3·75
CaO	11·08	10·10	10·20	8·67	1·79	5·40
Na ₂ O	1·02	1·40	3·02	5·82	·50	3·79
K ₂ O	·38	·66	1·33	1·13	5·25	·65
H ₂ O —	·11	·10	·10	·11	·14	·07
H ₂ O + ...	3·12	2·80	2·00	1·30	2·51	4·71
TiO ₂	1·35	1·69	1·30	1·55	1·29	·74
CO ₂	Trace	·14	2·98	5·15	3·40	3·43
P ₂ O ₅	·21	·38	·36	·17	·38	·20
FeAs ₂	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	·34	<i>Nil</i>
FeS ₂	·09	·06	<i>Nil</i>	<i>Nil</i>	7·16	Trace
Fe ₇ S ₈	<i>Nil</i>	<i>Nil</i>	·88	2·07	2·02	<i>Nil</i>
NiO	..	Trace	Trace	Trace	Trace	..
Cr ₂ O ₃	..	·01	·02	·02	·02	..
V ₂ O ₃	..	·09	·06	·11	·41	..
B ₂ O ₃	..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	·30	..
SO ₃	..	<i>Nil</i>	Trace	<i>Nil</i>	·14	..
Cu	..	Trace	Trace	Trace	Trace ⁽²⁾	..
Total	100·30	99·85	100·81	100·60	100·56 ⁽³⁾	100·87
Sp. gr.	..	3·042	2·901	2·781	2·925	2·70
Analyst	A.J.R.	H.B.	E.S.S.	E.S.S.	E.S.S.	A.J.R.
Date	1912.	1913.	1913.	1913.	1913.	1912.

(1) Exclusive of quartz veins; including quartz veins the rock mass contains 54·16% SiO₂.

(2) Cu 0·005%.

(3) Also gold, 12 dwts. 8 grs. per ton; silver, 10 dwts. 13 grs. per ton.

[12465.] Epidorite, altered dolerite. Dyke (?).

North of Santa Claus Alluvial Workings, N. of Ora Banda, Cen. Div. (H. 51).

Components: Felspar, epidote, hornblende, chlorite, zoisite (R.A.F.).

Reference: B. 54, pp. 32, 49, 50, 121.

[12410.] Porphyrite, uralitised. Dyke.

Below water level, Victorious G.M., Ora Banda, Cen. Div. (H. 51).

Components: Actinolite, epidote, zoisite, plagioclase, chlorite, biotite, sericite, quartz, ilmenite, leucoxene, apatite, calcite, pyrites (E.S.S.).

References: B. 54, pp. 25, 26, 95-109.

[12662.] Porphyrite, micacised, etc., and slightly weathered. Dyke.

Near lode, 240ft. level, Gimlet G.M., Ora Banda, Cen. Div. (H. 51).

Components: Biotite, epidote, zoisite, plagioclase, talc, sericite, calcite, ilmenite, pyrrhotite, apatite (E.S.S.).

Reference: B. 54, pp. 95-109.

[12985.] Porphyrite, carbonated, etc. Dyke.

On boundary of lode, 240ft. level, Gimlet G.M., Ora Banda, Cen. Div. (H. 51).

Components: Plagioclase, calcite, biotite, chlorite, ilmenite, sericite, zoisite, pyrrhotite, apatite (E.S.S.).

Reference: B. 54, pp. 95-109.

[12663.] Gold lode, altered porphyrite (12410). Shear zone in dyke.

240ft. level, Gimlet G.M., Ora Banda, Cen. Div. (H. 51).

Components: Sericite, dolomite, pyrite, pyrrhotite, arsenopyrite, leucoxene, ilmenite, chlorite, talc, chalcidony, apatite, tourmaline, plagioclase (E.S.S.).

Reference: B. 54, pp. 102-3.

[11636.] Porphyrite, chloritised and carbonated. Dyke.

W. of Hogan's Find, Mt. Monger, Cen. Div. (H. 51).

Components: Felspar, calcite, chlorite, biotite, kaolin, quartz.

TABLE F.—*continued.*

G.S.M. No. ..	[12731.]	[1936.]	[10415.]	[1800.]	[1745.]	[13451.]
Rock	Amphibolite.	Epidiorite.	Epidiorite.	Propylite.	Propylite.	Propylite.
Locality ..	Kal-goorlie.	Kal-goorlie.	Kal-goorlie.	Kal-goorlie.	Kal-goorlie.	Kal-goorlie.
SiO ₂	52·37	57·72	50·72	55·84	49·43	50·05
Al ₂ O ₃	13·90	9·68	13·93	10·38	13·00	12·77
Fe ₂ O ₃	2·37	6·49	1·93	4·39	·01	1·12
FeO	7·41	9·17	6·27	12·82	12·91	7·86
MnO	·24	·09	·41	·38	·52	·34
MgO	7·99	1·63	10·16	·54	1·87	6·51
CaO	10·81	5·05	13·18	4·18	6·23	8·68
Na ₂ O	1·52	3·92	1·04	3·40	1·97	1·34
K ₂ O	·06	·12	·18	·76	1·62	·48
H ₂ O —	·10	·16	·16	·05	·09	·13
H ₂ O + ...	2·68	1·51	1·55	1·83	1·26	4·42
TiO ₂	·77	1·13	·39	·62	·72	·33
ZrO ₂	..	..	<i>Nil</i>	..	..	..
CO ₂	·12	1·84	·18	4·92	9·92	6·31
P ₂ O ₅	·11	..	·18	..	..	·14
FeS ₂	·26	..	·15	·22	·34	·02
BaO	..	..	<i>Nil</i>	..	..	..
Cr ₂ O ₃	..	..	·04	..	..	·05
V ₂ O ₃	..	..	·11	..	..	·06
Total	100·71	98·51	100·58	100·33	99·89	100·61
Sp. gr.	3·00	3·04	3·07	2·90	2·93	2·79
Analyst	H.B.	C.C.W.	H.B.	C.G.G.	C.G.G.	E.S.S.
Date	1915	1901	1910	1901	1901	1915

[12731.] Chloritised Amphibolite, altered dolerite (?). Dyke or Archaean flow.

"A.I." G.M.L. 4385E., Kalgoorlie, Cen. Div. (H. 51).

Components: Actinolite, chlorite, zoisite, albite, ilmenite, leucoxene, pyrites, calcite (E.S.S.).

[1936.] Carbonated and chloritised Epidiorite, altered Dolerite. Dyke.

600ft. level, Hannans North G.M.L. 4274E, Mullingar, Kalgoorlie, Cen. Div. (H. 51).

Components: Albite, quartz, chlorite, zoisite, dolomite, epidote, magnetite, ilmenite, sericite, leucoxene (J.A.T.).

Reference: Q.J.G.S. 69, pp. 652, 3.

[10415.] Epidiorite, uralitised dolerite. Dyke.

Railway cutting, $1\frac{1}{4}$ miles W. of Quarry, Somerville, Kalgoorlie, Cen. Div. (H. 51).

Components: Hornblende, felspar, zoisite, quartz, chlorite, leucoxene, calcite (E.S.S.).

[1800.] Propylite, chloritised and carbonated dolerite. Dyke.

West cross-cut, 300ft. level, Golden Horsehoe G.M., Boulder, Kalgoorlie, Cen. Div. (H. 51).

Components: Chlorite, ankerite, calcite, quartz, albite, sericite, magnetite, ilmenite (E.S.S.).

Reference: B. 42, p. 123; Q.J.G.S. 69, p. 653.

[1745.] Propylite, chloritised and carbonated dolerite. Dyke.

Shaft on west side of Federal Road, opposite Kallaroo Railway Station, Boulder, Kalgoorlie, Cen. Div. (H. 51).

Components: Dolomite, chlorite, albite, sericite, quartz, ilmenite, pyrites (E.S.S.).

[13451.] Propylite, chloritised and carbonated dolerite. Dyke.

90ft. level, Fair Play Extended G.M.L. 4063E, Williamstown, Kalgoorlie, Cen. Div. (H. 51).

Components: Chlorite, calcite, albite, sericite, leucoxene (E.S.S.).

TABLE F--*continued.*

G.S.M. No. ..	[13773.]	[2817.]	[11107.]	[2219.]	[1739.]	[2943.]
Rock	Propy- lite.	" Calc- schist."	Chlori- toid schist.	Cerato- pyhre.	Porphy- rite.	Porphy- rite.
Locality ..	Kal- goorlie.	Kal- goorlie.	Kal- goorlie.	Kal- goorlie.	Kal- goorlie.	Kal- goorlie.
SiO ₂	49·81	60·73	50·94	62·16	60·01	63·05
Al ₂ O ₃	12·38	12·93	12·04	14·98	17·82	14·04
Fe ₂ O ₃	·78	..	2·74	·39	·54	..
FeO	7·03	3·67	9·44	3·03	1·65	5·36
MnO	·24	·13	1·06	·51	·09	·02
MgO	5·04	1·98	3·04	1·32	1·69	1·58
CaO	6·91	5·86	5·47	4·03	5·86	5·92
Na ₂ O	1·10	2·32	1·28	6·18	2·79	6·74
K ₂ O	1·74	1·54	·66	1·59	1·85	·62
H ₂ O—	·02	·29	·16	·07	·15	·04
H ₂ O+	2·82	1·08	2·81	·25	1·65	·26
TiO ₂	·60	·33	1·09	·16	·05	·97
ZrO ₂	..	..	Trace	..	..	..
CO ₂	10·92	8·32	8·24	5·65	5·50	1·47
P ₂ O ₅	·10	..	·45	..	..	..
FeS ₂	·30	..	·77	·60	1·88	..
BaO	..	..	·02	..	..	..
Cr ₂ O	·03	..	<i>Nil</i>	..	..	..
V ₂ O ₃	·03	..	·09	..	..	..
Total	99·85	99·18	100·30	100·92	101·53	100·07
Sp. gr. ..	2·85	2·76	2·88	2·72	2·71	2·75
Analyst ..	H.B.	C.C.W.	H.B.	C.G.G.	C.G.G.	C.C.W.
Date	1915	1901	1910	1901	1901	1901

[13773.] Propylite, slightly foliated, carbonated and chloritised dolerite (?). Archaean flow or tuff (?).

A.W.A. United G.M.L. 4441E, Williamstown, Kalgoorlie, Cen. Div. (H. 51).

Components: Chlorite, dolomite, albite, sericite, leucoxene, pyrites (E.S.S.).

[2817.] "Calc-schist," foliated and carbonated porphyrite. Dyke.

200ft. level, Mt. Charlotte G.M.L. 211E, N.E. side of city, Kalgoorlie, Cen. Div. (H. 51).

Components: Ankerite, albite, sericite, leucoxene, quartz (E.S.S.).

[11107.] Chloritoid schist, foliated and carbonated dolerite (?). Dyke or Archaean flow (?).

Shaft 10 chains W. of T.L. 15, Lake View Townsite, Kalgoorlie, Cen. Div. (H. 51).

Components: Ankerite, albite, sericite, chloritoid, chlorite, rutile, quartz, magnetite, tourmaline (E.S.S.).

Reference: B. 42, p. 142.

[2219.] Carbonated ceratophyre. Dyke.

700ft. level, Golden Gate G.M.L. 749E, Boulder, Kalgoorlie, Cen. Div. (H. 51).

Components: Albite, ankerite, calcite, quartz, sericite, chlorite, rutile (E.S.S.).

Reference: Q.J.G.S. 69, pp. 658-9.

[1739.] Carbonated porphyrite. Dyke.

400ft. level, Main shaft, Ivy G.M.L. 4320E, Mullingar, Kalgoorlie, Cen. Div. (H. 51).

Components: Albite, sericite, calcite, ankerite, quartz, pyrites (E.S.S.).

[2943.] Carbonated porphyrite. Dyke.

Water shaft, near W. corner of Reserve A9286, S.W. side of city, Kalgoorlie, Cen. Div. (H. 51).

Components: Plagioclase, quartz, zoisite, hornblende, chlorite, sericite, calcite, leucoxene (E.S.S.).

TABLE F.—*continued.*

G.S.M. No. ..	[12483.]	[12477.]	[11802.]	[11524.]	[11754.]	[1/39.]
Rock	Tourma- line Rock.	Porphy- rite.	Horn- blende gneiss.	Amphibo- lite.	Amphibo- lite.	(L6404D) Amphibo- lite.
Locality ..	Binduli.	Binduli.	Gibraltar.	Southern Cross.	Southern Cross.	Westonia.
SiO ₂	52·56	57·22	50·41	63·20	52·27	50·69
Al ₂ O ₃	20·83	15·91	18·30	14·55	8·10	5·97
Fe ₂ O ₃	?	1·93	2·11	·07	2·37	2·31
FeO	6·31	4·66	11·20	4·01	22·32	8·04
MnO	<i>Nil</i>	·22	..	·23	·20	·25
MgO	5·18	5·66	3·27	4·84	7·84	17·85
CaO	·57	3·59	9·15	4·73	1·90	11·26
Na ₂ O	1·14	3·98	2·07	5·51	·32	·32
K ₂ O	·10	1·60	·85	·04	1·94	·38
H ₂ O—	·06	·21	·12	·33	·22	·04
H ₂ O+	3·05	3·20	1·58	·51	1·52	2·22
TiO ₂	2·09	·85	..	1·06	·64	·35
CO ₂	·10	1·49	·61	·14	·06	<i>Nil</i>
P ₂ O ₅	2·08	·14	..	·65	·38	·17
FeS ₂	·26	·11	..	·26	·19	·09
B ₂ O ₃	5·93	..	..	..	..	..
Cr ₂ O ₃	..	..	..	..	..	·39
Carbon	..	..	..	..	·19	..
Total	100·26	100·77	99·67	100·13	100·46	100·46
Sp. gr.	..	2·75	..	..	..	..
Analyst	H.B.	A.J.R.	E.S.S.	H.B.	H.B.	H.B.
Date	1913	1913	1912	1912	1912	1914

[12483.] Weathered tourmaline rock, altered dyke rock (?).
55 chains S.E. of S. corner of Stock Quarantine Reserve 8787,
Binduli, Cen. Div. (H. 51).

Components: Tourmaline, kaolin, apatite, quartz (E.S.S.).

Reference: Bulletin 56, p. 69.

[12477.] Crushed and chloritised porphyrite. Dyke.
Shaft near centre of W.R. 3341, adjacent to Townsite, Binduli, Cen. Div. (H. 51).

Components: Albite, quartz, chlorite, biotite, calcite, epidote, apatite, leucoxene (R.A.F.).

Reference: B. 56, p. 63.

[11802.] Hornblende gneiss. Origin uncertain.

Great Gala G.M.L. 1666, Gibraltar, Cen. Div. (H. 51).

Components: Hornblende, felspar, biotite, magnetite, quartz, muscovite (R.A.F.).

References: B. 53, pp. 22, 50, 68.

[11524.] Amphibolite, contact altered. An altered dolerite (?).
N.E. corner of G.M.L. 274, Blackbourne's, Southern Cross,
Cen. Div. (H. 50).

Components: Tremolite, felspar, quartz, iron ore, kaolin, apatite (R.A.F.).

References: B. 49, pp. 30, 89.

[11754.] Garnet Amphibolite. Origin doubtful.

Great Southern G.M.L. 1674, Southern Cross, Cen. Div. (H. 50).

Components: Actinolite, garnet, chlorite, felspar, quartz, biotite, graphite (R.A.F.).

References: B. 49, pp. 81, 82.

[1/39.] (L. 6404D) Amphibolite. Dyke.
536 feet in Duff's Bore, Edna May G.M., Westonia, Cen. Div.
(H. 50).

Components: Actinolite, iron ore, biotite (E.S.S.).

TABLE F.—*continued.*

G.S.M. No. ..	[1/39.]	[1/52.]	[8155.]	[5963.]	[5650.]	[5961.]
Rock	(L6406D) Diorite.	Amphibo- lite.	Eclogite.	Horn- blende Schist.	Amphibo- lite.	Biotite Schist.
Locality ..	Westonia.	Mt. Jackson.	Ravens- thorpe.	Norse- man.	Norse- man.	Norse- man.
SiO ₂	51·46	49·17	62·23	49·66	50·08	53·12
Al ₂ O ₃	11·43	15·39	11·90	14·52	14·85	17·99
Fe ₂ O ₃	1·38	1·52	·08	3·11	1·21	3·97
FeO	8·21	8·73	10·46	11·78	8·27	8·37
MnO	·30	·21	·56	1·53	·69	·31
MgO	12·33	8·29	4·09	5·04	7·21	6·15
CaO	10·83	11·11	6·16	9·82	12·60	·63
Na ₂ O	1·40	2·22	1·47	·72	1·69	1·02
K ₂ O	·58	·06	·29	1·40	·15	5·75
H ₂ O—	·03	·10	·07	·05	·13	·14
H ₂ O+	1·71	2·20	·34	·46	·91	1·58
TiO ₂	·58	·59	1·51	1·43	·63	1·16
CO ₂	<i>Nil</i>	·06	·23	·24	1·15	·18
P ₂ O ₅	·25	·10	·28	..	..	..
FeS ₂	·03	Trace	·79	·07	·17	·07
Cr ₂ O ₃	·08	..	..	..	..	..
V ₂ O ₃	·04	..	..	..	..	..
Total	100·64	99·75	100·46	99·83	99·74	100·44
Sp. gr. ..	..	2·84	2·96	3·09	2·97	2·87
Analyst ..	H.B.	H.B.	J.H.B.	C.C.W.	J.H.B.	C.C.W.
Date	1914	1915	1908	1905	1904	1905

[1/39.] (L. 6406D). Diorite, somewhat hydrated. Dyke.

658-674 feet, Duff's Bore, Edna May G.M., Westonia, Cen.

Div. (H. 50).

Components: Hornblende, labradorite, magnetite, ilmenite, apatite (E.S.S.).

[1/52.] Amphibolite. Uralitised dolerite. Dyke.

10 miles S.E. of Mt. Jackson Range, Cen. Div. (H. 50).

Components: Hornblende, plagioclase, ilmenite, leucoxene, sphene, zoisite, epidote, chlorite, magnetite, quartz, apatite (E.S.S.).

[8155.] Eclogite. Altered dolerite (?).

$\frac{1}{2}$ mile N.W. of Last Chance Copper Mine, Ravensthorpe Range, N.E. of Ravensthorpe, S.W. Div. (I. 51).

Components: Hornblende, quartz, albite, garnet, epidote, ilmenite, zoisite (E.S.S.).

[5963.] Hornblende schist. Altered dolerite. Dyke.

100ft. level, Bon Accord G.M.L. 95, $1\frac{1}{2}$ miles E. of Mararoa G.M., Norseman, Euc. Div. (I. 51).

Components: Hornblende, biotite, feldspar, quartz, calcite, ilmenite.

Reference: B. 21, p. 30.

[5650.] Amphibolite. Archaean flow (?).

Cliff on west side of Lake Cowan at 102 m. 13 ch. on Railway, N.W. of Norseman, Euc. Div. (I. 51).

Components: Hornblende, iron ores, quartz (E.S.S.).

Reference: B. 21, pp. 31, 32.

[5961.] Biotite schist. Altered dolerite. Dyke.

Bon Accord G.M.L. 95, $1\frac{1}{2}$ miles E. of Mararoa G.M., Norseman, Euc. Div. (I. 51).

Components: Biotite, feldspar, quartz, calcite, iron ores (E.S.S.).

Reference: B. 21, p. 30.

TABLE G.—METASOMATIC IGNEOUS ROCKS—SILICA 30 TO 47 PER CENT.

G.S.M. No. ..	[3777.]	[5787.]	[5777.]	[5768.]	[5756.]	[5755.]
Rock	Epido- site.	Magnesite schist.	Horn- blende schist.	Chlorite schist.	Chlorite schist.	Talc- chlorite schist.
Locality ..	Napier Broome Bay.	Warra- woona.	Warra- woona.	Warra- woona.	Warra- woona.	Warra- woona.
SiO ₂	45·59	26·65	43·90	41·88	43·47	43·25
Al ₂ O ₃	13·54	2·03	9·13	10·13	14·87	9·98
Fe ₂ O ₃	9·39	2·06	1·20	<i>Nil</i>	3·35	1·93
FeO	4·87	3·52	10·48	9·59	14·93	10·04
MnO	·37	·35	·05	·32	·10	·54
MgO	3·01	28·89	19·17	7·20	12·64	22·48
CaO	20·19	2·68	7·46	13·06	1·18	5·31
Na ₂ O	·57	·29	·57	1·30	·55	·49
K ₂ O	·06	·09	·09	·10	·13	Trace
H ₂ O—	·28	·16	·04	·07	·26	·20
H ₂ O+	·68	·92	4·68	3·51	6·82	4·74
TiO ₂	·68	·16	·30	1·15	1·48	·50
CO ₂	<i>Nil</i>	32·60	2·46	11·60	<i>Nil</i>	·17
FeS ₂	·17	·17	·05	·34	·11	·07
Total	99·40	100·57	99·58	100·25	99·89	99·70
Sp. gr. ..	3·28	2·86	2·93	2·79	2·88	2·94
Analyst ..	C.C.W.	J.H.B.	J.H.B.	J.H.B.	C.C.W.	J.H.B.
Date	1902	1905	1904	1904	1904	1904

[3777.] Epidosite, epidotised dolerite. Dyke (?).

3 miles N. of Survey Station F.B. 79, Napier Broome Bay, Kim. Div. (D. 52).

Components: Epidote, felspar, quartz, leucoxene (E.S.S.).

[5787.] Magnesite schist, carbonated and foliated peridotite. Dyke or boss.

Juneau G.M.L. 479, Warrawoona, N.W. Div. (F. 50).

Components: Magnesite (ferruginous), quartz, limonite (E.S.S.).

[5777.] Hornblende schist, altered dolerite. Dyke.

Imperialist G.M.L. 564, Warrawoona, N.W. Div. (F. 50).

Components: Hornblende, chlorite, calcite, sphene (E.S.S.).

[5768.] Chlorite schist, altered dolerite. Dyke.

May-be G.M.L. 531, Warrawoona, N.W. Div. (F. 50).

Components: Chlorite, calcite, felspar, quartz, ilmenite (E.S.S.).

[5756.] Chlorite schist, altered dolerite. Dyke.

Tom Thumb Lode Claim 141, Warrawoona, N.W. Div. (F. 50).

Components: Chlorite, quartz, felspar, sphene (E.S.S.).

[5755.] Tale chlorite schist, altered pyroxenite (?).

Golden Gate G.M.L. 607, Warrawoona, N.W. Div. (F. 50).

Components: Tale, chlorite, actinolite, magnesite.

TABLE G.—*continued.*

G.S.M. No. ..	[5757.]	[5778.]	[12568.]	[5376.]	[7561.]	[11765.]
Rock	Carbonated Peridotite.	Carbonated Amphibolite.	Serpentine.	Serpentine.	Propylite.	Carbonated Peridotite.
Locality ..	Warrawoona.	Warrawoona.	Soanesville.	Box Soak.	Bangemall.	Meekatharra.
SiO ₂	30·63	45·68	38·84	38·91	45·36	35·69
Al ₂ O ₃	1·68	8·94	2·10	1·08	13·78	3·07
Fe ₂ O ₃	5·94	2·23	9·52	10·30	1·74	·87
FeO	4·72	5·91	·53	1·80	11·54	8·59
MnO	·11	·09	Trace	·08	·17	·13
MgO	32·30	12·25	34·06	36·65	6·23	20·46
CaO	Trace	12·56	·03	Trace	8·07	·81
Na ₂ O	·41	1·82	·10	·40	1·71	·08
K ₂ O	·11	·12	·13	Trace	·33	1·48
H ₂ O—	·15	·07	1·00	·28	·22	·11
H ₂ O+	·52	1·92	12·81	10·89	4·47	·66
TiO ₂	·52	·40	·04	·06	1·69	·98
CO ₂	23·03	8·34	Trace	<i>Nil</i>	4·49	26·20
P ₂ O ₅	..	..	Trace	..	·26	·04
FeS ₂	·20	·09	·19	<i>Nil</i>	·17	·88
Cr ₂ O ₃	..	..	·79	..	..	·40
V ₂ O ₃	..	..	..	..	..	<i>Nil</i>
Total	100·32	100·42	100·14	100·45	100·23	100·45
Sp. gr.	2·91	2·82	..	2·69	2·85	..
Analyst	J.H.B.	C.C.W.	A.J.R.	E.S.S.	C.C.W.	H.B.
Date	1904	1904	1912	1904	1907	1911

[5757.] Carbonated and foliated peridotite. Dyke.

10 chains E. of G.M.L. 531, Warrawoona, N.W. Div. (F. 50).

Components: Magnesite, talc, magnetite, chlorite, limonite (E.S.S.).

Reference: B. 40, p. 160.

[5778.] Carbonated amphibolite, altered dolerite. Dyke.

Imperialist G.M.L. 564, Warrawoona, N.W. Div. (F. 50).

Components: Hornblende, calcite, chlorite, ilmenite, feldspar, quartz (E.S.S.).

[12568.] Serpentine, altered peridotite. Batholith.

Asbestos Leases, Soanesville, N.W. Div. (F. 50).

Components: Serpentine (partly opaline), magnetite, chromite, calcite, chlorite (?) (R.A.F.).

[5376.] Serpentine, altered augite peridotite. Dyke (?).

Hills near Box Soak, 30 miles S.E. of Port Hedland, N.W. Div. (F. 50).

Components: Serpentine, magnetite, actinolite (E.S.S.).

[7561.] Propylite, chloritised and carbonated dolerite. Dyke (?). Bangemall, N.W. Div. (G. 50).

Components: Chlorite, albite, epidote, calcite, quartz, leucoxene (J.A.T.).

Reference: B. 33, p. 160.

[11765.] Carbonated peridotite. Dyke (?).

Ingliston Extended G.M., Meekatharra, Mur. Div. (G. 50).

Components: Mesitite, quartz, fuchsite, pyrite, chromite, ilmenite, calcite (R.A.F.).

TABLE G.—*continued.*

G.S.M. No. ..	[Ga.]	[13190A.]	[5087.]	[12970.]	[11681.]	[2117B.]
Rock	Weathered Amphibolite.	Chlorite Schist.	Talc-chlorite schist.	Serpentine.	Carbonated Amphibolite. Breccia.	Amphibolite.
Locality ..	Gabarnintha.	Sandstone.	Leonora.	Ora Banda.	Kanowna.	Kalgoorlie.
SiO ₂	42·74	41·85	42·17	40·60	33·32	46·38
Al ₂ O ₃	7·66	15·96	9·29	1·48	5·93	12·70
Fe ₂ O ₃	16·68	1·25 ₍₁₎	..	7·77	·32	1·76
FeO	7·78	9·22	8·18	5·36	6·35	10·22
MnO	..	..	·55	·21	·43	·30
MgO	15·38	8·43	24·71	31·33	18·17	13·45
CaO	6·64	8·28	4·06	1·06	10·57	7·28
Na ₂ O	·36	·18	·45	·08	·78	1·12
K ₂ O	·10	1·36	·26	·03	Trace	·24
H ₂ O—	·10	·21	·02	1·13	·03	·21
H ₂ O+	2·32	6·67	2·97	10·01	1·30	4·39
TiO ₂	..	..	·55	·14	..	·77
ZrO ₂	..	..	..	..	..	<i>Nil</i>
CO ₂	Trace	6·42	6·70	<i>Nil</i>	23·06	·15
P ₂ O ₅	..	..	..	·09	..	·25
FeS ₂	..	..	·28	·02	..	·41
BaO	..	..	..	..	..	<i>Nil</i>
Cr ₂ O ₃	..	<i>Nil</i>	..	·60	..	Trace
V ₂ O ₃	..	<i>Nil</i>	..	..	..	Trace
Carbon	..	·14	..	..	..	..
Total	99·76	100·32	100·19	99·91	100·31	99·63
Sp. gr.	..	2·82	2·85	..	..	2·91
Analyst	H.B.	A.J.R.	C.C.W.	H.B.	M.A.B.	H.B.
Date	1909	1913	1903	1913	1912	1910

(1) Approximate, owing to presence of finely divided graphite.

[Ga.] Weathered amphibolite, uralitised dolerite or pyroxenite. Dyke.

Gabanintha, Cen. Div. (G. 50).

Components: Hornblende, felspar, chlorite, zoisite, epidote (E.S.S.).

[13190A.] Chlorite schist, altered dolerite. Dyke.

450ft. level, Black Range G.M., Sandstone, Cen. Div. (G. 50).

Components: Chlorite, calcite, quartz, leucoxene, graphite (R.A.F.).

Reference: B. 62, p. 29.

[5087.] Talc-chlorite schist, altered pyroxenite (?). Dyke. Tower Hill G.M.L. 4390, Leonora, Cen. Div. (H. 51).

Components: Talc, chlorite, dolomite, biotite, rutile (E.S.S.).

[12970.] Serpentine, altered pyroxenite or augite peridotite. Dyke.

Great Gimblet G.M.L. 1662, S.W. of Township, Ora Banda, Cen. Div. (H. 51).

Components: Serpentine, magnetite, limonite, haematite (?), mica (?), chromite (R.A.F.).

References: B. 62, pp. 49, 123.

[11681.] Carbonated amphibolite breccia, altered pyroxenite (?).

North of Fitzroy Lead, Kanowna, Cen. Div. (H. 51).

Components: Ankerite, hornblende, chlorite, quartz, albite, rutile (E.S.S.).

[2117B.] Amphibolite (lustre mottled), altered hornblende dolerite. Dyke.

Main Shaft, Great Boulder No. 2 South G.M.L. 1219E, Golden Horseshoe Estates, Boulder, Kalgoorlie, Cen. Div. (H. 51).

Components: Actinolite, basaltic hornblende, epidote, chlorite, zoisite, albite, calcite, leucoxene (E.S.S.).

Reference: Q.J.G.S. 69, pp. 639-41.

TABLE G.—*continued.*

G.S.M. No. ..	[11003.]	[10436.]	[11105.]	(K230).	[11184.]	[1728.]
Rock	Amphibolite.	Amphibolite.	Propylite.	Propylite.	Propylite.	Propylite.
Locality ..	Kal-goorlie.	Kal-goorlie.	Kal-goorlie.	Kal-goorlie.	Kal-goorlie.	Kal-goorlie.
SiO ₂	46·26	44·17	45·52	44·61	43·13	42·96
Al ₂ O ₃	9·01	10·57	10·87	18·07	12·16	9·63
Fe ₂ O ₃	·67	9·20	·84	·55	1·54	4·47
FeO	10·41	10·92	7·92	7·71	10·64	12·73
MnO	·56	·51	·32	..	·60	..
MgO	19·65	4·56	11·72	3·39	4·79	4·38
CaO	6·94	9·12	6·80	7·28	8·71	8·24
Na ₂ O	·30	1·94	2·24	·14	1·70	2·66
K ₂ O	·10	·16	·04	1·54	·48	·56
H ₂ O—	·14	·16	·06	·10	·12	·10
H ₂ O+	4·42	2·28	3·32	2·42	2·59	2·00
TiO ₂	·54	4·99	·43	·31	1·22	1·04
ZrO ₂	<i>Nil</i>	<i>Nil</i>	·01	..	<i>Nil</i>	..
CO ₂	·20	·35	9·52	13·86	11·56	11·65
P ₂ O ₅	·21	·40	·45	..	·88	..
FeS ₂	·19	·26	·17	..	·39	·32
BaO	<i>Nil</i>	·01	<i>Nil</i>	..	<i>Nil</i>	..
Cr ₂ O ₃	·20	<i>Nil</i>	·08	..	<i>Nil</i>	..
V ₂ O ₃	·10	·19	·30	..	·04	..
Total	99·87	99·79	100·61	99·98	100·54	100·74
Sp. gr.	2·96	3·27	2·82	2·84	2·93	2·97
Analyst	H.B.	H.B.	H.B.	H.B.	H.B.	E.S.S.
Date	1909	1910	1909	1910	1910	1901

[11003.] Amphibolite, uralitised dolerite. Dyke.

Outerop, Outridge G.M.L. 1187E, 35 chains N.E. of Mt. Charlotte Reservoir, Kalgoorlie, Cen. Div. (H. 51).

Components: Actinolite, hornblende, chlorite, serpentine (?), leucoxene, calcite, apatite, allanite (E.S.S.).

References: B. 42, pp. 34, 133, 134, 147.

[10436.] Amphibolite, uralitised gabbro pegmatite, Segregation in Dyke.

West side of Mt. Gledden, Eagle Hawk United G.M.L. 3770E, Kalgoorlie, Cen. Div. (H. 51).

Components: Hornblende, felspar, zoisite, epidote, quartz, leucoxene, ilmenite, calcite (E.S.S.).

Reference: B. 42, pp. 31, 132.

[11105.] Propylite, chloritised and carbonated dolerite. Dyke.

200 feet, Hidden Secret G.M.L. 4001E, Williamstown, Kalgoorlie, Cen. Div. (H. 51).

Components: Ankerite, chlorite, quartz, albite, ilmenite (E.S.S.).

[K230.] Propylite, chloritised and carbonated dolerite. Dyke. Kalgoorlie, Cen. Div. (H. 51).

Components: Ankerite, chlorite, quartz, sericite, albite, leucoxene (E.S.S.).

[11184.] Propylite, chloritised and carbonated dolerite. Dyke.

400 feet, Lake View Consols G.M., Boulder, Kalgoorlie, Cen. Div. (H. 51).

Components: Ankerite, chlorite, albite, sericite, quartz, leucoxene, ilmenite, pyrites (E.S.S.).

[1728.] Propylite, chloritised and carbonated dolerite. Dyke.

Quarry, Central Boulder G.M.L. 24E, 30 chains E. of Fimiston, Kalgoorlie, Cen. Div. (H. 51).

Components: Ankerite, calcite, chlorite, albite, sericite, leucoxene, ilmenite, quartz, magnetite (E.S.S.).

TABLE G.—*continued.*

G.S.M. No. ..	[1753.]	[1730.]	[1750.]	[1796.]	[1751.]	[2502.]
Rock	“ Calc- schist.”	Chlorite schist.	Chlorite schist.	“ Calc- schist.”	Carbon- ated propylite.	Carbon- ated propylite.
Locality ..	Kal- goorlie.	Kal- goorlie.	Kal- goorlie.	Kal- goorlie.	Kal- goorlie.	Kal- goorlie.
SiO ₂	46·94	45·55	40·61	44·96	42·01	39·83
Al ₂ O ₃	12·49	10·88	8·85	11·46	8·42	11·83
Fe ₂ O ₃	·33	4·14	..	4·02	2·45	·20
FeO	9·20	13·18	12·42	14·70	15·76	9·51
MnO	·32	..	·21	·77	·41	·54
MgO	3·56	2·31	4·50	·50	1·67	5·13
CaO	6·43	7·52	14·27	4·66	7·07	9·78
Na ₂ O	1·84	3·04	·84	4·40	2·62	2·18
K ₂ O	2·57	·26	3·17	1·47	1·15	·44
H ₂ O—	·09	·27	·10	<i>Nil</i>	·23	·11
H ₂ O+	·30	1·74	2·30	·13	·67	1·07
TiO ₂	·14	·63	·15	·65	·81	1·14
ZrO ₂	..	..	..	..	..	·02
CO ₂	13·41	10·26	12·75	12·42	15·65	17·32
P ₂ O ₅	..	..	..	..	..	·27
FeS ₂	2·25	·34	·29	·19	·30	·24
BaO	..	..	..	..	..	<i>Nil</i>
Cr ₂ O ₃	..	..	..	..	..	·01
V ₂ O ₃	..	..	..	..	..	·33
Total	99·87	100·12	100·91	100·33	99·22	100·21
Sp. gr	2·94	2·91	2·90	2·83	3·00	2·93
Analyst ..	C.G.G.	E.S.S.	C.G.G.	C.G.G.	C.G.G.	H.B.
Date	1901	1901	1901	1901	1901	1909

[1753.] "Calc-schist," carbonated chlorite schist, altered dolerite. Dyke.

From lode channel, 400ft. level, Ivanhoe G.M.L. 31E, Boulder, Kalgoorlie, Cen. Div. (H. 51).

Components: Ankerite, sericite, albite, quartz, leucoxene, pyrites (E.S.S.).

Reference: Q.J.G.S. 69, p. 653; B. 42, p. 69.

[1730.] Chlorite schist, altered dolerite. Dyke.

Main shaft, Imperial Boulder G.M.L. 1222E, near S.W. corner of Lake View Townsite, Kalgoorlie, Cen. Div. (H. 51).

Components: Chlorite, ankerite, albite, quartz, sericite, calcite, magnetite, ilmenite, pyrites (E.S.S.).

[1750.] Chlorite schist, altered dolerite. Dyke.

Waddington shaft, Oroya South Block G.M.L. 532E, Boulder, Kalgoorlie, Cen. Div. (H. 51).

Components: Ankerite, chlorite, albite, sericite, quartz, calcite, leucoxene, ilmenite (E.S.S.).

Reference: B. 42, p. 123.

[1796.] Calc schist, carbonated dolerite. Dyke.

300ft. level, Golden Horseshoe G.M., Boulder, Kalgoorlie, Cen. Div. (H. 51).

Components: Siderite, calcite, ankerite, albite, quartz, sericite, ilmenite, leucoxene (E.S.S.).

[1751.] Carbonated propylite, altered dolerite. Dyke.

400ft. level, Ivanhoe G.M., Boulder, Kalgoorlie, Cen. Div. (H. 51).

Components: Ankerite, albite, quartz, siderite, sericite, magnetite, chlorite, leucoxene (E.S.S.).

Reference: Q.J.G.S. 69, p. 653.

[2502.] Carbonated propylite, altered dolerite. Dyke.

350ft. level, Trafalgar G.M.L. 3031, Lake View, Kalgoorlie, Cen. Div. (H. 51).

Components: Ankerite, albite, chlorite, quartz, muscovite, leucoxene, ilmenite (E.S.S.).

TABLE G.—*continued.*

G.S.M. No. ..	[3218.]	[3294.]	[12240.]	(11029.)	[10913.]	[375.]
Rock	Serpen- tine.	Serpen- tine.	Talc- chlorite rock.	Carbon- ated peridotite.	Carbon- ated peridotite.	Carbon- ated peridotite.
Locality ..	Kal- goorlie.	Kal- goorlie.	Kal- goorlie.	Kal- goorlie.	Kal- goorlie.	Kal- goorlie.
SiO ₂	39·35	39·06	35·90	42·65	33·80	31·07
Al ₂ O ₃	6·15	3·36	13·48	4·69	5·72	5·05
Fe ₂ O ₃	4·75	2·77	7·04	·61	·40	1·49
FeO	5·17	5·93	4·12	7·64	8·70	7·64
MnO	1·21	·77	..	·48	·19	·10
MgO	28·51	32·94	15·69	15·22	19·95	17·49
CaO	3·10	2·43	5·81	7·94	1·34	5·46
Na ₂ O	·73	·12	·26	·30	·30	3·82
K ₂ O	·15	·08	2·00	·06	2·11	·11
H ₂ O—.. ..	·14	·54	1·84	·09	·09	·07
H ₂ O+	9·05	8·38	4·71	1·32	·59	·05
TiO ₂	·60	·51	..	·20	·33	·26
ZrO ₂	..	<i>Nil</i>	..	·01	·02	..
CO ₂	<i>Nil</i>	2·88	9·22	18·07	25·98	27·24
P ₂ O ₅	·01	·26	..	·19	·11	·05
FeS ₂	<i>Nil</i>	(SO ₃)·37	..	·30	·24	·06
BaO	..	<i>Nil</i>	..	<i>Nil</i>	<i>Nil</i>	..
NiO	·36	..	..	..	..	·12
Cr ₂ O ₃	·40	·24	..	·40	·50	·35
V ₂ O ₃	Trace	·01	..	<i>Nil</i>	(·005)	Trace
Total	99·68	100·65	100·07	100·16	100·37	100·43
Sp. gr. ..	2·81	2·72	..	2·84	2·97	2·89
Analyst ..	C.C.W.	H.B.	H.B.	H.B.	E.S.S.	C.G.G.
Date	1902	1909	1912	1909	1909	1901

[3218.] Serpentine, altered augite peridotite. Dyke.
10 chains W. of Leviathan Battery, Hannans Lake, Kalgoorlie,
Cen. Div. (H. 51).

Components: Serpentine, bastite (?), actinolite, magnetite,
chromite (E.S.S.).

Reference: Q.J.G.S. 69, p. 635.

[3294.] Serpentine, altered augite peridotite. Dyke.
25 chains E.N.E. of Trig. Station, Mt. Hunt, Kalgoorlie, Cen.
Div. (H. 51).

Components: Serpentine, bastite (?), actinolite, magnetite,
chromite (E.S.S.).

Reference: B. 42, p. 144.

[12240.] Tale-chlorite rock, altered peridotite (?). Dyke.
Shaft near centre of S.E. boundary, Hyman G.M.L. 4406, Mul-
lingar, Kalgoorlie, Cen. Div. (H. 51).

Components: Tale, chlorite, sericite, dolomite (R.A.F.).

[11029.] Carbonated peridotite. Dyke.
Quarry, Bonnie Play G.M.L. 4088E, Williamstown, Kalgoorlie,
Cen. Div. (R. 51).

Components: Mesitite, quartz, zeolite (?), fuchsite, rutile.

[10913.] (19a) Carbonated peridotite. Dyke.
Shaft near centre of Hyman G.M.L. 4406E, Mullingar, Kal-
goorlie, Cen. Div. (H. 51).

Components: Mesitite, quartz, fuchsite, rutile, pyrites (E.S.S.).

Reference: Q.J.G.S. 69, pp. 636, 637.

[375.] Carbonated Peridotite. Dyke.
S. point of Serpentine Bay, Hannans Lake, Kalgoorlie, Cen.
Div. (H. 51).

Components: Mesitite, actinolite, quartz, magnetite, chromite,
rutile (E.S.S.).

TABLE G.—concluded.

G.S.M. No. ..	[12070.]	[1/60.]	[1/77.]	L2474D.	[1/39.] (L6405D)	[1/39.] (L6403D)
Rock	Graphitic Schist.	Carbon- ated Perido- tite.	Carbon- ated Perido- tite.	Horn- blende Schist.	Altered Perido- tite.	Altered Perido- tite.
Locality ..	Cool- gardie.	Marda.	Marda.	Southern Cross.	Westonia.	Westonia.
SiO ₂	38·49	41·95	33·04	44·76	46·28	43·60
Al ₂ O ₃	21·43	7·05	8·63	15·76	7·11	3·46
Fe ₂ O ₃	?	·31	·29	2·93	2·12	3·49
FeO	3·60	11·22	13·22	21·89	7·47	4·46
MnO	..	·26	·16	..	·25	·19
MgO	5·95	16·97	14·99	5·90	23·00	33·24
CaO	5·39	·64	·77	1·56	9·12	4·69
Na ₂ O	·42	·10	·14	·14	·74	·22
K ₂ O	3·68	·83	·76	3·70	·30	·07
H ₂ O—	·92	·06	·08	·20	·03	·16
H ₂ O+	2·60	3·66	3·49	2·55	2·12	5·56
TiO ₂	..	·32	·71	..	·59	·27
CO ₂	14·14	16·20	13·07	·06	<i>Nil</i>	<i>Nil</i>
P ₂ O ₅	..	·15	·10	..	·18	·53
FeS ₂	..	·09	10·21	..	·39	·09
Cr ₂ O ₃	..	·34	·18	..	·49	·16
V ₂ O ₃	..	..	·01	..	·03	..
Carbon ..	3·33	..	·12	·14	..	..
Total	99·95	100·15	99·97	99·59	100·22	100·19
Sp. gr. ..	..	2·91	3·09	..	..	..
Analyst ..	H.B.	E.S.S.	H.B.	H.B.	H.B.	H.B.
Date	1912	1915	1915	1912	1914	1914

[12070.] Graphitic Schist, crushed and carbonated Dolerite (?).
 Railway cutting, 2 miles E. of Coolgardie, Cen. Div. (H. 51).
 Components: Sericite, ankerite, chlorite, albite, graphite
 (E.S.S.).

Reference: B. 53, p. 73.

[1/60.] Carbonated Peridotite. Dyke.

Great Unknown G.M., Marda, Cen. Div. (H. 50).

Components: Mesitite, chlorite, talc, sericite (E.S.S.).

[1/77.] Carbonated Peridotite pyritised. Dyke.

Great Unknown G.M., Marda, Cen. Div. (H. 50).

Components: Mesitite, chlorite, talc, sericite, pyrites, graphite
 (E.S.S.).

L. 2474D. Hornblende-garnet Schist, altered dolerite (?).

Southern Cross, Cen. Div. (H. 50).

Components: Hornblende, garnet, felspar, biotite, ilmenite.

[1/39.] (L. 6405D). Slightly serpentinised Peridotite (IV.
 1.3.2(1).2; Rossweinose, near Wehrlose). Dyke (?).

570 feet, Duff's Bore, Edna May G.M., Westonia, Cen. Div.
 (H. 50).

Components: Actinolite, olivine, magnetite, chromite, ilmenite,
 biotite, serpentine (E.S.S.).

[1/39.] (L. 6403D). Serpentinised Peridotite. Dyke (?).

490 feet, Duff's Bore, Edna May G.M., Westonia, Cen. Div.
 (H. 50).

Components: Actinolite, serpentine, olivine, magnetite, ilmenite,
 chromite, biotite (E.S.S.).

**TABLE H.—SEDIMENTARY CARBONATE ROCKS—
MAGNESIA UNDER 10 PER CENT.**

G.S.M. No. ..	[6449.]	[7547.]	Ha.	Hb.	[13670.]	Hc.
Rock	Marble.	Marble.	Traver- tine.	Traver- tine.	Traver- tine.	Traver- tine.
Locality ..	Hamers- ley Range.	Bange- mall.	Southern Cross.	Southern Cross.	Southern Cross.	Southern Cross.
SiO ₂	1·69	11·02	11·18	8·79	10·42	12·99
Al ₂ O ₃	·17	·57	2·53	2·30	3·85	2·62
Fe ₂ O ₃	·57	<i>Nil</i>	2·66	1·33	1·57	1·32
FeO	·88	·95	..	..	..	..
MnO	·64	·16	..	..	..	..
MgO	·38	3·53	1·94	5·52	·22	1·97
CaO	53·24	45·68	42·69	40·90	45·06	43·92
Na ₂ O	·35	·32	..	..	..	..
K ₂ O	<i>Nil</i>	·42	..	..	..	..
H ₂ O—	·04	·06	..	..	..	..
H ₂ O+	·14	·25	..	..	3·44	..
SO ₃	Trace	<i>Nil</i>	..	..	..	..
CO ₂	42·65	37·24	37·89 ⁽¹⁾	40·67 ⁽¹⁾	35·56	37·59 ⁽¹⁾
P ₂ O ₅	·02	·16	·11	Trace	<i>Nil</i>	<i>Nil</i>
Organic matter	Trace	·26	Present	Present	Present	Present
Total	100·77	100·62	99·00	99·51	100·12	100·41
Sp. gr.	2·73	2·73	..	..	..	..
Analyst	E.S.S.	C.C.W.	J.H.B.	C.C.W.	A.J.R.	H.B.
Date	1906	1907	1908	1908	1914	1912

⁽¹⁾ Ignition loss.

[6449.] Light brown Marble. Palæozoic.

Near Weelumerina Spring, Hamersley Range, N.W. Div. (F. 50).

Components: Calcite, iron hydrates (J.A.T.).

Reference: B. 33, p. 153.

[7547.] Black Marble. Palæozoic.

South leg of Bangemall anticline, Bangemall, N.W. Div. (G. 50).

Components: Calcite, dolomite, quartz, mica, iron hydrates, carbonaceous matter (J.A.T.).

Reference: B. 33, p. 157.

Ha. Concretionary Travertine.

Hb, [13670], and **Hc.** Massive Travertine. Recent.

Lime kilns, 2 miles S. of Southern Cross, Cen. Div. (H. 50).

Components: Calcite, clay, iron hydrates, quartz, fragments of amphibolite, organic matter (E.S.S.).

TABLE H.—*continued.*

G.S. No. ..	Hd.	He.	L7751.	L7756.	L7764.	L7765.
Rock	Traver- tine.	Traver- tine.	Dune sand.	Dune sand.	Dune sand.	Dune sand.
Locality ..	Southern Cross.	Kunun- oppin.	Dongara.	Dongara.	Dongara.	Dongara.
SiO ₂	10·90	25·79	7·07	6·75	9·10	6·32
Al ₂ O ₃	3·99	2·70	·45	·54	·45	·03
Fe ₂ O ₃	1·67	·80	..	..	..	..
FeO	..	..	·81	·42	2·07	·82
MgO	1·71	4·10	2·40	2·50	2·87	3·04
CaO	43·11	33·64	46·85	47·00	44·44	46·78
H ₂ O—	..	..	·40	·48	·63	·38
CO ₂	38·25 ⁽¹⁾	33·20 ⁽¹⁾	39·83 ⁽²⁾	39·71 ⁽²⁾	38·98 ⁽²⁾	40·37 ⁽²⁾
P ₂ O ₅	..	..	·15	·11	·10	·11
Organic	..	..	2·04	2·46	1·25	2·07
NaCl	..	..	Trace	·03	·11	·08
Total	99·63	100·23	100·00	100·00	100·00	100·00
Sp. gr.	..	..	..	..	..	..
Analyst	H.B.	H.B.	E.S.S.	E.S.S.	H.B.	H.B.
Date	1912	1912	1915	1915	1915	1915

(1) Ignition Loss. (2) Calculated.

Hd. Concretionary Travertine. Recent.

Lime kilns, 2 miles S. of Southern Cross, Cen. Div. (H. 50).

Components: Calcite, kaolin, iron hydrates, quartz, fragments of amphibolite, organic matter (E.S.S.).

He. Massive Travertine. Recent.

Kununoppin, S.W. Div. (H. 50).

Components: Calcite, dolomite, quartz, kaolin, iron hydrates (E.S.S.).

L. 7751, 7756, 7764, 7765. Dune sand. Recent.

North end of Ularino Hill, Loc. 1263, S. side of Irwin River, Dongara, S.W. Div. (H. 50).

Components: Foraminifera, powdered mollusca and calcareous algae, quartz, felspar (E.S.S.).

TABLE H.—*continued*.

G.S. No. ..	L7757.	L7758.	L7759.	L7760.	L7761.	L7762.
Rock	Dune sand.	Dune sand.	Dune sand.	Dune sand.	Dune sand.	Dune sand.
Locality ..	Dongara.	Dongara.	Dongara.	Dongara.	Dongara.	Dongara.
SiO ₂	7·27	8·82	8·58	2·10	1·90	3·96
Al ₂ O ₃	·67	·47	·21	·22	·23	Trace
FeO	·47	·60	·34	·25	·24	·33
MgO	2·65	3·16	2·88	3·36	3·34	3·38
CaO	46·22	45·86	46·38	48·74	48·62	47·92
H ₂ O	·64	·52	·61	·66	·61	·38
CO ₂	39·30	39·66	39·72	41·93	41·62	41·35
P ₂ O ₅	·11	·10	·09	·09	·09	·09
Organic ..	2·62	·74	1·14	2·59	3·24	2·58
NaCl	·05	·07	·05	·06	·11	·01
Total	100·00	100·00	100·00	100·00	100·00	100·00
Analyst ..	E.S.S.	H.B.	H.B.	H.B.	H.B.	H.B.
Date	1915	1915	1915	1915	1915	1915

L7757, L7758. Dune sand. Recent.

South end of Ularino Hill, Dongara, S.W. Div. (H. 50).

L7759. Dune sand. Recent.

Loc. 1794, 3 miles S. of Railway Station, Dongara, S.W. Div.

L7760, 7761. Dune sand. Recent.

Obelisk, Denison Common, 1½ miles E. of Jetty, Dongara, S.W. Div. (H. 50).

L7762. Dune sand. Recent.

One-third mile S. of Obelisk, Denison Common, Dongara, S.W. Div. (H. 50).

Components: (L7757-62): Foraminifera, powdered mollusca and calcareous algæ, quartz, sponge spicules, felspar (E.S.S.).

TABLE H.—*continued.*

G.S. No. ..	L7763.	L7753.	L7754.	L7755.	L7752.	Hf.
Rock	Dune sand.	Dune sand.	Dune sand.	Dune sand.	Dune sand.	Chalk.
Locality ...	Dongara.	Dongara.	Dongara.	Dongara.	Dongara.	Gingin.
SiO ₂	3·82	59·80	72·24	7·05	11·13	15·23
Al ₂ O ₃	Trace	·79	1·48	1·31	·79	1·70
Fe ₂ O ₃	..	..	..	..	..	2·04
FeO	·24	2·42	2·35	·79	·98	..
MgO	2·74	1·09	1·00	2·48	2·40	1·51
CaO	48·72	17·99	11·37	46·63	44·82	43·17
H ₂ O— ⁵⁴	·46	..	..	·38	·42	..
CO ₂	41·22 ₍₁₎	17·65 ₍₁₎	11·43 ₍₁₎	39·63 ₍₁₎	38·24 ₍₁₎	35·63
P ₂ O ₅	·11	..	..	·11	·11	..
Organic	2·67	..	..	1·62	1·06	..
NaCl	·02	..	..	Trace	·05	..
Total	100·00	99·74	99·87	100·00	100·00	99·28
Analyst	H.B.	E.S.S.	E.S.S.	E.S.S.	E.S.S.	J.H.B.
Date	1915	1915	1915	1915	1915	1909

(1) Calculated.

L7763. Dune sand. Recent.

Alongside obelisk, Point Leander, Dongara, S.W. Div. (H. 50).

Components: Foraminifera, powdered mollusca and calcareous algae, quartz, sponge spicules (E.S.S.).

L7753, 7754. Dune sand. Recent.

West side of Dongara Trig., Dongara, S.W. Div. (H. 50).

Components: Quartz, foraminifera, powdered mollusca and algae, felspar, sponge spicules (E.S.S.).

L7755. Dune sand. Recent.

Dongara Trig., Dongara, S.W. Div. (H. 50).

Components: Same as 7763 with a little felspar.

L7752. Dune sand. Recent.

South end of hill, north side of Irwin River, one mile S.W. of Railway Station, Dongara, S.W. Div. (H. 50).

Components: Same as 7755.

Hf. Chalk. Cretaceous.

One Tree Hill, Gingin, S.W. Div. (H. 50).

Components: Foraminifera, fragments of mollusca, quartz, flint, glauconite, kaolin (E.S.S.).

TABLE H.—*continued.*

G.S. No.	..	Hg.	Hh.	Hi.	Hj.	Hk.	[4670.]
Rock	..	Chalk.	Chalk.	Chalk.	Chalk.	Chalk.	Chalk.
Locality	..	Gingin.	Gingin.	Gingin.	Gingin.	Gingin.	Gingin.
SiO ₂	..	16·72	20·28	27·04	25·56	15·25	15·09
Al ₂ O ₃	..	1·95	3·40	4·36	3·54	2·30	3·15
Fe ₂ O ₃	..	1·90	2·53	3·29	3·32	2·33	1·29
MgO	..	1·52	1·27	1·16	1·14	·99	1·32
CaO	..	42·46	39·50	34·69	35·11	42·95	42·41
H ₂ O—	..	..	..	..	..	..	1·99
H ₂ O+	..	..	..	..	..	..	1·18
SO ₃	..	..	..	..	..	..	·13
CO ₂	..	35·03	32·34	28·46	28·84	34·76	33·02
Total	..	99·58	99·32	99·00	97·61	98·58	99·58
Analyst	..	J.H.B.	J.H.B.	J.H.B.	J.H.B.	J.H.B.	E.S.S.
Date	..	1909	1909	1909	1909	1909	1902
G.S. No.	..	He.	Hm.	Hm.	Ho.	Hp.	L4051D.
Rock	..	Marl.	Lime- stone.	Dune Sand.	Marl.	Marl.	Marl.
Locality	..	Bulls- brook.	West Subiaco.	Rocking- ham.	Lake Clifton.	Lake Preston.	Bussel- ton.
SiO ₂	..	13·14	13·96	53·30	1·61	7·20	6·88
Al ₂ O ₃	..	1·64	} 26	Trace	} 24	..	} 2·10
Fe ₂ O ₃	..	·96		1·06		..	
MgO	..	1·58	1·12	·86	1·01	1·97	Nil
CaO	..	44·44	45·82	23·94	48·88	44·88	50·26
H ₂ O—	..	..	..	·28	..	} 1·19	} 1·17
H ₂ O+	..	..	..	1·08	..		
SO ₃	..	..	..	Trace	·39	..	..
CO ₂	..	36·59	37·09	19·46	37·07	37·35	39·41
P ₂ O ₅	..	..	..	..	·09	..	Trace
Organic	..	..	1·75 ⁽¹⁾	..	8·93 ⁽²⁾	7·34	..
NaCl	..	..	..	·02	2·02	..	..
Total	..	99·74	100·00	100·00	100·24	99·93	99·82
Analyst	..	D.G.M.	H.B.	E.S.S.	E.S.S.	E.S.S.	A.J.R.
Date	..	1913	1913	1914	1912	1913	1914

⁽¹⁾ Includes Water.⁽²⁾ Includes Nitrogen 0·32 per cent.

Hg-Hk and [4670.] Chalk. Cretaceous.

One Tree Hill, Gingin, S.W. Div. (H. 50).

Components: Foraminifera, fragments of mollusca, quartz, flint, glauconite, kaolin (E.S.S.).

He. Marl. Quaternary (?).

Bullsbrook, S.W. Div. (H. 50).

Components: Calcite, quartz, kaolin (E.S.S.).

Hm. Coastal Limestone. Pliocene or later.

Lime kilns, two miles W. of Subiaco, Perth, S.W. Div. (H. 50).

Components: Calcite, quartz (E.S.S.).

Hn. Dune sand. Recent.

Between Warnbro Sound and Lake Wolyungup, Rockingham, S.W. Div. (I. 50).

Components: Quartz, foraminifera, fragments of mollusca, limonite (E.S.S.).

Ho. Marl. Recent.

Bed of Lake Clifton, S.E. Div. (I. 50).

Components: Aragonite, calcite, organic matter, salt, gypsum, quartz, diatoms, and other organic remains (E.S.S.).

Hp. Marl. Recent.

Bed of Lake Preston, S.W. Div. (I. 50).

Components: Calcite, organic matter, diatoms and other organic remains (E.S.S.).

L. 4051D. Marl. Recent.

Busselton, S.W. Div. (L. 50).

Components: Calcite, quartz, kaolin (E.S.S.).

TABLE H.—*concluded.*

G.S.M.No. ..	[3411.]	L7892D.	[3053.]	[3044.]	[3045.]	[3047.]
Rock	Limestone	Limestone.	Limestone.	Limestone.	Limestone.	Limestone.
Locality ..	Jarrahdene	Denmark.	Nullarbor Plains.	Nullarbor Plains.	Nullarbor Plains.	Nullarbor Plains.
SiO ₂	5·53	11·68	5·49	·70	·45	·36
Al ₂ O ₃	·45	} ·62	3·41	·24	} ·65	} ·38
Fe ₂ O ₃	Trace		Traces	Traces		
FeO	·59	..	1·47	·56	..	..
MnO	·81	..	..	..	..	..
MgO	·59	1·11	1·40	·68	1·20	·67
CaO	50·46	45·90	49·34	53·73	54·52	55·23
Na ₂ O	·06	..	..	..	..	..
K ₂ O	·11	..	..	..	..	..
H ₂ O —	·16	..	..	..	..	..
H ₂ O + ...	·29	..	..	..	..	..
SO ₃	Trace	..	..	..	..	..
CO ₂	41·10	37·19 ₍₁₎	(38·39)	(44·09)	(43·18)	(43·36)
Organic ..	Trace	(3·50) ₍₂₎	..	..	..	..
Total	100·15	100·00	100·00	100·00	100·00	100·00
Sp. gr	2·59	..	2·58	..	..	..
Analyst ..	E.S.S.	E.S.S.	C.C.W.	E.S.S.	C.C.W.	C.C.W.
Date	1902.	1915.	1901.	1901.	1901.	1901.

(1) Calculated.

(2) Includes water.

[3411.] Coastal Limestone. Pliocene (?).

Top of hill at entrance to Lake Cave, Jarrahdene District, S.W. Div. (I. 50).

Components: Foraminifera, fragments of calcareous algæ and mollusca, secondary calcite, quartz, felspar (E.S.S.).

Reference: B. 44, pp. 13, 14.

L. 7892D. Coastal Limestone. Pliocene or later.

Hills on South Coast, W. side of Wilson's Inlet, Denmark, S.W. Div. (I. 50).

Components: Foraminifera, fragments of calcareous algæ and mollusca, secondary calcite, quartz, felspar (E.S.S.).

[3053.] Concretionary Limestone. Recent.

Near 276-mile post, Transcontinental Railway, Nullarbor Plains, Euc. Div. (H. 52).

Components: Calcite, kaolin (E.S.S.).

[3044.] Limestone. Tertiary.

Nullarbor Plains, 70 miles N.N.W. of Eyre, Euc. Div. (H. 51).

Components: Calcite, kaolin, quartz (E.S.S.).

[3045.] Limestone. Tertiary.

Nullarbor Plains, 55 miles N. by W. of Eyre, Euc. Div. (H. 51).

Components: Calcite, kaolin (E.S.S.).

[3047.] Limestone. Tertiary.

Yayouldle Rock hole, Nullarbor Plains, 30 miles N. by W. of Eyre, Euc. Div. (H. 51).

Components: Calcite, kaolin (E.S.S.).

TABLE I.—SEDIMENTARY CARBONATE ROCKS—
MAGNESIA OVER 10 PER CENT.

G.S.M. No. ..	[5765.]	[7615.]	[7730.]	[7617.]	[7546.]
Rock	Dolomite.	Dolomite.	Dolomite.	Dolomite.	Dolomite. Marble.
Locality ..	Warrawoona.	Secret Creek.	Coorara clay-pan.	Dead Finish.	Gascoyne River.
SiO ₂	17·63	3·15	·23	15·78	10·86
Al ₂ O ₃	4·28	·06	·20	2·50	·67
Fe ₂ O ₃	1·97	Trace	Trace	2·11	Trace
FeO	..	·90	·15	6·18	·80
MnO	Trace	·14	·30	1·52	..
MgO	14·74	21·65	21·25	12·09	21·42
CaO	24·63	29·59	30·43	22·84	29·80
Na ₂ O	·92	·05	<i>Nil</i>	·35	·32
K ₂ O	·43	·06	<i>Nil</i>	·47	·06
H ₂ O —	·05	·02	·04	·19	·13
H ₂ O + ...	·70	·05	·06	·17	2·43
TiO ₂	·20	..	..	<i>Nil</i>	..
SO ₃	..	Trace	<i>Nil</i>	<i>Nil</i>	·23
CO ₂	34·94	44·72	47·44	35·02	33·20
P ₂ O ₅	..	Trace	·10	·53	·11
FeS ₂	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	..
Total	100·49	100·39	100·20	99·75	100·25
Sp. gr.	2·76	2·85	2·87	2·89	2·76
Analyst ..	C.C.W.	C.C.W.	C.C.W.	H.B.	C.C.W.
Date	1904.	1907.	1908.	1907.	1907.

[5675.] Dolomite. Precambrian (?).

Near Ironclad Battery, M.A. 19, Warrawoona, N.W. Div. (F. 50).

Components: Dolomite, quartz, calcite, albite, muscovite, limonite, amphibole (E.S.S.).

Reference: B. 40, p. 157.

[7615.] Dolomite. Palæozoic.

Secret Creek, N.W. Div. (F. 50).

Components: Dolomite, muscovite, quartz (J.A.T.).

Reference: B. 33, p. 162.

[7730.] Dolomite. Palæozoic.

Coorara Clay-pan, Ashburton River, N.W. Div. (F. 50).

Components: Dolomite, quartz, iron hydrates (J.A.T.).

Reference: B. 33, p. 170.

[7617.] Dolomite. Palæozoic.

Trig. Station C. 8, near Dead Finish, Upper Ashburton River, N.W. Div. (F. 50).

Components: Dolomite, calcite, quartz, muscovite, apatite, magnetite, iron hydrates (J.A.T.).

Reference: B. 33, p. 164.

[7546.] Dolomite marble, Palæozoic.

$\frac{1}{4}$ mile N.E. of Trig. Station K. 31, Gascoyne River, N.W. Div. (G. 50).

Components: Dolomite, chondrodite, chlorite, serpentine, iron ores (J.A.T.).

Reference: B. 33, p. 156.

TABLE I.—*continued.*

G.S.M. No. ..	[7724.]	[7725.]	[7726.]	[7548.]	[13923.]
Rock	Dolomite. Marble.	Dolomite.	Dolomite. Marble.	Dolomite.	Dolomite.
Locality ..	Irregularly Creek.	Irregularly Creek.	Irregularly Creek.	Bangemall.	Mt. Russell.
SiO ₂	3·14	8·27	1·96	44·95	7·08
Al ₂ O ₃	·02	·52	·60	4·00	·78
Fe ₂ O ₃	·33	<i>Nil</i>	·55	Trace	1·90
FeO	·39	·35	·11	2·01	·68
MnO	·68	·46	·39	·43	·78
MgO	20·70	19·49	22·13	11·31	18·92
CaO	29·53	27·57	29·42	14·23	27·24
Na ₂ O	·05	Trace	·09	·24	·05
K ₂ O	·12	·12	·04	·10	·25
H ₂ O —	·14	·03	·11	·11	·16
H ₂ O + ...	·08	·06	Trace	1·24	·42
TiO ₂	<i>Nil</i>	·13	..	..	·06
SO ₃	·13	·05	Trace	·03	<i>Nil</i>
CO ₂	44·89	43·17	45·18	21·32	41·85
P ₂ O ₅	·11	Trace	Trace	·18	·25
FeS ₂	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
Total	100·32	100·22	100·58	100·36	100·42
Sp. gr.	2·85	2·85	2·89	2·67	2·80
Analyst ..	H.B.	J.H.B.	D.G.M.	E.S.S.	E.S.S.
Date	1907.	1908.	1907.	1907.	1915.

[7724.] Dolomite marble. Palæozoic.

The Gorge, Irregully Creek, N.W. Div. (F. 50).

Components: Dolomite, quartz, iron hydrates (J.A.T.).

Reference: B. 33, p. 166.

[7725.] Dolomite. Palæozoic.

The Gorge, Irregully Creek, N.W. Div. (F. 50).

Components: Dolomite, quartz, iron oxides (J.A.T.).

Reference: B. 33, p. 166.

[7726.] Dolomite marble. Palæozoic.

The Gorge, Irregully Creek, N.W. Div. (F. 50).

Components: Dolomite, tremolite, mica, chlorite, iron ores (J.A.T.).

Reference: B. 33, p. 167.

[7548.] Dolomite. Palæozoic.

North leg of anticline, Bangemall, N.W. Div. (G. 50).

Components: Dolomite, quartz, iron hydrates, tourmaline, mica (J.A.T.).

Reference: B. 33, p. 159.

[13923.] Dolomite. Palæozoic.

Mt. Russell, Cen. Div. (G. 50).

Components: Dolomite, quartz, sericite, magnetite, ilmenite, apatite, psilomelane, limonite (E.S.S.).

TABLE I.—*concluded.*

G.S.M. No. 	Ia.	Ib.	[5654.]	[3043.]
Rock 	Marl.	Marl.	Dolomite.	Dolomite.
Locality 	Rockingham.	Rockingham.	Norseman.	Goddard's Creek.
SiO ₂	4·02 ⁽¹⁾	4·45 ⁽³⁾	4·98	2·38
Al ₂ O ₃	Trace	Trace	4·64	2·43
Fe ₂ O ₃	·24	Trace	Trace	1·02
FeO 	..	..	·92	1·48
MnO 	..	..	Trace	..
MgO 	12·72	21·24	16·66	16·40
CaO 	35·20	24·20	28·00	31·36
Na ₂ O 	..	..	·50	..
K ₂ O 	..	..	·23	..
H ₂ O - 	2·38	2·92	1·73	..
H ₂ O + ...	9·42 ⁽²⁾	12·75 ⁽²⁾	·62	..
TiO ₂	..	..	·11	..
SO ₃	·31	·25	..	..
CO ₂	35·69	33·65	41·32	(44·93)
NaCl 	·02	·54	..	..
Total 	100·00	100·00	99·71	100·00
Sp. gr. 	..	..	2·72	2·69
Analyst 	E.S.S.	E.S.S.	C.C.W.	E.S.S.
Date 	1914.	1914.	1904.	1901.

⁽¹⁾ Comb. SiO₂, 3·37%.⁽²⁾ Includes organic.⁽³⁾ Comb. SiO₂, 4·36%.

Ia. Marl. Recent.

Bed of Lake Wolyungup (near edges), Rockingham, S.W. Div.
(I. 50).

Components: Calcite (aragonite ?), hydromagnesite (?), sepiolite (?). (E.S.S.)

Ib. Marl. Recent.

Bed of Lake Wolyungup (centre), Rockingham, S.W. Div.
(I. 50).

Components: Hydromagnesite (?), calcite (aragonite ?), sepiolite(?).

[5654.] Dolomite, Tertiary or Quaternary.

Quarry on M.L. 1, east side of Lake Cowan, Norseman, Euc. Div. (I. 51).

Components: Dolomite, calcite, quartz, felspar, kaolin.
(E.S.S.)

Reference: B. 21, pp. 21, 22.

[3043.] Dolomite, Tertiary or Quaternary.

South of Goddard's Creek, Euc. Div. (H. 51).

Components: Dolomite, calcite, quartz, kaolin. (E.S.S.)

TABLE J.—SEDIMENTARY SILICEOUS ROCKS—
SILICA OVER 75 PER CENT.

G.S.M. No. ..	[7564.]	[5084.]	[1731.]	[12509.]	[6109.]
Rock	Quartz Schist.	Andalusite Schist.	Slate.	Slate.	Sandstone.
Locality ..	Bangemall.	Leonora.	Kalgoorlie.	Binduli.	Norseman.
SiO ₂	92·30	76·71	84·07	84·14	91·80
Al ₂ O ₃	2·98	20·08	9·03	10·18	3·31
Fe ₂ O ₃	·89	1·70	·42	?	1·06
FeO	..	..	·45	·44	<i>Nil</i>
MnO	<i>Nil</i>	<i>Nil</i>	Trace	<i>Nil</i>	·27
MgO	·62	·06	·24	·82	·23
CaO	<i>Nil</i>	·56	·21	·22	·14
Na ₂ O	·52	·07	1·64	·05	·31
K ₂ O	1·06	·11	2·21	2·41	·05
H ₂ O —	·12	·21	·20	·18	·53
H ₂ O + ...	·33	·24	1·05	1·56	1·04
TiO ₂	·22	·66	1·16	·25	1·17
B ₂ O ₃	..	..	..	·05	..
CO ₂	·04	<i>Nil</i>	·07	·14	<i>Nil</i>
P ₂ O ₅	·04	..	..	·02	..
FeS ₂	·20	<i>Nil</i>	·04	·06	·07
Graphite ..	<i>Nil</i>	<i>Nil</i>	Trace	·12	..
Total	99·61	100·40	100·79	100·64	99·98
Sp. gr.	2·61	2·81	2·66	..	2·57
Analyst	D.G.M.	C.C.W.	E.S.S.	E.S.S.	C.C.W.
Date	1907.	1903.	1901.	1912.	1905.

[7564.] Quartz schist. Palæozoic.

North leg of anticline, Bangemall, N.W. Div. (G. 50).

Components: Quartz, muscovite, limonite. (J.A.T.)

Reference: Bull. 33, p. 161.

[5084.] Andalusite schist. Archæan.

Near Trig. Station, Leonora, Cen. Div. (H. 51).

Components: Quartz, andalusite, sericite, rutile. (E.S.S.)

[1731.] Siliceous slate, possibly a crushed and silicified intrusive, archæan (?).

East of Idaho G.M.L. 4317E, Boulder, Kalgoorlie, Cen. Div. (H. 51).

Components: Quartz, sericite, chlorite, albite, rutile, calcite. (E.S.S.)

Reference: B. 6, pp. 76, 77.

[12509.] Siliceous slate.

40 chains S.W. of S.W. corner of New Year Gift G.M.L. 4483. Binduli, Cen. Div. (H. 51).

Components: Quartz, sericite, tourmaline, felspar, rutile, carbon, chlorite (?), calcite. (R.A.F.)

[6019.] Sandstone. Archæan or Palæozoic

Open cut, Stella May Quartz Claim 151, Nerseman, Euc. Div. (I. 51).

Components: Quartz, kaolin, felspar, iron ores. (E.S.S.)

TABLE J.—*continued.*

G.S.M. No. ..	[5038.]	[5039.]	[4362.]	Ja.	Jb.	[6645.]
Rock	Diatomite.	Diatomite.	Diatomite.	Diatomite.	Diatomite.	Diatomite.
Locality ..	Wanneroo.	Wanneroo.	Wanneroo.	Wanneroo.	Wanneroo.	Cape Arid.
SiO ₂	32·99	54·24	49·08 ⁽¹⁾	67·72	92·10	83·84
Al ₂ O ₃	1·84	3·14	3·51	9·98	6·59	·98
Fe ₂ O ₃	Traces	Traces	Traces	Traces	Traces	·54
MgO	·58	·42	·05	Traces	·09	·32
CaO	1·07	·78	·16	·22	·30	·31
Na ₂ O	·15	·15	·22	..	·41	..
K ₂ O	·03	·04	·06	..	·11	..
H ₂ O — ..	12·38	10·27	11·20	5·63	<i>Nil</i>	2·39
Ign. Loss ⁽²⁾ ..	49·11	29·79	35·79	16·69	<i>Nil</i>	10·94
SO ₃	·21	·65	Trace	..	..	..
NaCl	1·83	1·20	·21	..	·40	·68
Total	100·19	100·68	100·28	100·24	100·00	100·00
Sp. gr. ..	..	..	·383 ⁽³⁾	..	·232	..
Analyst ..	C.C.W.	C.C.W.	E.S.S.	E.S.S.	E.S.S.	E.S.S.
Date	1903.	1903.	1902.	1902.	1902.	1906.
SiO ₂ in calcined earth	85·25	89·45	92·10	86·91	92·10	96·74

(1) SiO₂ insoluble in NaOH, 1·74% (Quartz grains).

(2) Includes much organic matter.

(3) Bulk specific gravity, air dried, 0·383; ditto, freshly dug and wet, 1·145.

[5038.] Diatomite, air dried. Recent.

Lake Marginniup, Wanneroo, S.W. Div. (H. 50).

[5039.] Diatomite, air dried. Recent.

Lake Jandabup, Wanneroo, S.W. Div. (H. 50).

[4362.] Diatomite, air dried. Recent.

Ja. Diatomite, partly calcined.

Jb. Diatomite, calcined.

North end of Lake Gngara, Wanneroo, S.W. Div. (H. 50).

Components of all above: Water, organic matter, diatom frustules, sponge (Ephydatia) spicules, kaolin, quartz.

Reference: A.R. 1902, p. 11; A.R. 1903, p. 28.

[6645.] Diatomite, air dried. Recent.

Swamp near Cape Arid, Euc. Div. (I. 51).

Components: Same as Wanneroo diatomite.

TABLE J.—concluded.

G.S.M. No. ..	Jc.	Jd.	Je.	[7152.]	[7153.]
Rock	Sand.	Sandstone.	Sandstone.	Sandstone.	Sandstone.
Locality ..	Busselton.	Donnybrook.	Donnybrook.	Cape Riche.	Cape Riche.
SiO ₂	95·46	96·88	98·28	82·58	83·62 ⁽¹⁾
Al ₂ O ₃	2·76	·24	·09	5·95	6·25
Fe ₂ O ₃	1·00	1·26	·57	2·34	1·95
MgO	Trace	·03	·11	·39	·57
CaO	Trace	·08	·08	<i>Nil</i>	·13
K ₂ O	..	·03	·01	..	..
H ₂ O —	} ·78 ⁽²⁾ {	·26	·14	3·49	3·50
H ₂ O + ...		·84	·64	2·82	2·74
CO ₂	Trace	·08	·16	<i>Nil</i>	<i>Nil</i>
P ₂ O ₅	..	·01	·03	..	..
FeS ₂	..	·01	·02	..	..
NaCl	..	·06	·03	..	..
Alks. and loss ..	..	..	..	2·43	1·24
Total	100·00	99·78	100·16	100·00	100·00
Sp. gr.	..	2·48	2·41	2·20	2·18
Analyst ..	C.C.W.	Dougall.	Dougall.	E.S.S.	E.S.S.
Date	1908.	1902.	1902.	1907.	1907.

(¹) Includes 60·22 % SiO₂ soluble in 5% NaOH.

(²) Includes some organic matter.

Jc. Sand. Recent dunes.

Near Busselton, S.W. Div. (I. 50).

Components: Quartz, kaolin, limonite, organic matter. (E.S.S.)

Jd & Je. Sandstone. Mesozoic (?).

Donnybrook, S.W. Div. (I. 50).

Components: Quartz, kaolin, felspar, ankerite (?), muscovite. (E.S.S.)

[7152 & 7153.] Spicular sandstone, Miocene.

Cape Riche, S.W. Div. (I. 50).

Components: Opal (Marine sponge spicules), quartz, kaolin, limonite, felspar, muscovite. (E.S.S.)

TABLE K.—SEDIMENTARY SILICEOUS ROCKS—
SILICA UNDER 75 PER CENT.

G.S.M. No. ..	[3758.]	[10988.]	[10596-9.]	[10644.]	[7732.]	[13839.]
Rock	Slate.	Slate.	Slates.	Slate.	Phyllite.	Phyllite.
Locality ..	Synnott Tableland.	Whim Creek.	Whim Creek.	Egina.	Uaroo.	Mt. Eger- ton.
SiO ₂	68·60	72·73	61·00	46·57	58·84	61·24
Al ₂ O ₃	11·70	17·45	20·67	35·41	21·59	17·33
Fe ₂ O ₃	Trace.	<i>Nil</i>	..	..	4·76	1·23
FeO	6·02	·43	6·11	·25	·60	6·54
MnO	<i>Nil</i>	<i>Nil</i>	·19	<i>Nil</i>	·26	·18
MgO	5·36	·44	3·18	·65	2·31	3·28
CaO	·18	·11	·92	·28	·29	<i>Nil</i>
Na ₂ O	·94	·62	1·06	1·96	1·34	·26
K ₂ O	3·18	4·14	2·04	7·11	5·34	4·72
H ₂ O —	·20	·11	·20	·50	·16	·07
H ₂ O + ...	2·64	1·52	3·39	4·37	2·52	3·96
TiO ₂	·64	·35	1·00	2·00	1·48	·52
CO ₂	<i>Nil</i>	·12	·10	<i>Nil</i>	<i>Nil</i>	·15
P ₂ O ₅	..	·38	·30	·47	·36	·29
FeS ₂	<i>Nil</i>	1·23	·19	·13	<i>Nil</i>	·04
Graphite ..	..	·16	·14	·40	..	..
Total	99·46	99·79	100·49	100·10	99·85	99·81
Sp. gr.	2·64	2·75	..	..	2·81	2·83
Analyst	C.G.G.	H.B.	H.B.	H.B.	C.C.W.	H.B.
Date	1902.	1910.	1910.	1910.	1907.	1915.

[3758.] Slate.

Synnott Tableland, Kim. Div. (E. 51).

Components: Quartz, sericite, chlorite, limonite. (E.S.S.)

[10988.] Slate.

Bore core, 300 feet depth, Whim Well C.M., Whim Creek, N.W. Div. (F. 50).

Components: Quartz, sericite, kaolin, carbonates, iron ore, graphite. (L.G.)

Reference: B. 41, p. 43.

[10596-9.] Slates (mixed sample of four specimens).

Whim Creek, N.W. Div. (F. 50).

Components: Quartz, sericite, albite, chlorite, rutile, pyrite, graphite. (E.S.S.)

Reference: B. 41, pp. 13, 59.

[10644.] Slate.

Egina, N.W. Div. (F. 50).

Components: Sericite, quartz, chlorite, pyrite, graphite. (E.S.S.)

[7732.] Phyllite.

Dark Horse Copper Mine, P.A. 13, Uaroo, N.W. Div. (F. 50).

Components: Quartz, muscovite, haematite, rutile, kyanite (?). (J.A.T.)

Reference: B. 33, p. 170.

[13839.] Phyllite.

State Battery Well, Mt. Egerton, N.W. Div. (G. 50).

Components: Sericite, chlorite, quartz, iron ore, apatite, zoisite (?), albite (?). (R.A.F.)

TABLE K.—*continued.*

G.S.M. No. ..	[3949.]	[12487.]	[11752.]	[11453.]	L7989 _F .	L7990 _D .
Rock	Shale.	Altered arkose.	Sericite schist.	Garnet Phyllite.	Shale.	Shale.
Locality ..	Kanowna.	Binduli.	Southern Cross.	Southern Cross.	Dongara.	Dongara.
SiO ₂	44·16	70·83	71·24	69·77	62·74	45·74
Al ₂ O ₃	30·38	12·66	19·58	18·38	13·32	11·01
Fe ₂ O ₃	4·44	2·36	·76	2·16	5·56	4·26
FeO	..	2·79	·26	·28 ⁽¹⁾	..	..
MnO	<i>Nil</i>	..	..	Trace	·45	·33
MgO	·70	4·67	·46	·48	1·39	1·38
CaO	·53	·29	·07	·60	1·30	14·86
Na ₂ O	1·05	2·63	<i>Nil</i>	·56	·66	·54
K ₂ O	·33	1·22	5·62	·46	3·46	2·09
H ₂ O —	3·81	·20	·13	·52	4·16	2·68
H ₂ O + ...	11·80	2·81	2·27	2·35	6·46 ⁽²⁾	4·68 ⁽²⁾
TiO ₂	3·74	..	..	1·39	·70	·51
CO ₂	..	<i>Nil</i>	..	·34	·38	12·10
P ₂ O ₅	..	..	..	·18	..	..
FeS ₂	..	..	..	·32	..	..
SO ₃	..	..	..	·90	..	..
Graphite ..	..	..	..	1·25	..	..
NaCl	..	..	..	..	<i>Nil</i>	<i>Nil</i>
Total	100·94	100·46	100·39	99·94	100·58	100·18
Sp. Gr.	..	2·65	..	2·84	..	..
Analyst	C.C.W.	A.J.R.	H.B.	H.B.	H.P.W.	H.P.W.
Date	1903.	1913.	1912.	1911.	1915.	1915.

⁽¹⁾ Approximate only.⁽²⁾ Includes some organic matter.

[3949.] Shale ("Auriferous Pug"): Quaternary (?).

Deep Lead, Kanowna, Cen. Div. (H. 51).

Components: Kaolin, sericite, tale, doelterite, gold (1.958 ozs. per ton). (E.S.S.)

[12487.] Altered arkose.

20 chains W. of S.W. corner of Exhibition G.M.L. 3790E, Binduli, Cen. Div. (H. 51).

Components: Quartz, felspar, sericite, chlorite, biotite, kaolin, epidote, iron ores. (R.A.F.).

Reference: B. 56, p. 70.

[11752.] Sericite Schist.

Shaft 2½ chains S.E. of S. peg of G.M.L. 1536, Southern Cross, Cen. Div. (H. 50).

Components: Sericite, quartz, rutile. (R.A.F.).

Reference: B. 49, p. 54.

[11456.] Garnet Phyllite.

North end of G.M.L. 348, near Rifle Range, Southern Cross, Cen. Div. (H. 50).

Components: Garnet, quartz, muscovite, chlorite, epidote, iron ore, leucoxene. (R.A.F.)

Reference: B. 49, pp. 25, 53.

L. 7989D and **L7990D**. Clay shale, surface material. Age (?).

Dongara, S.W. Div. (H. 50).

Components: Quartz, kaolin, muscovite, calcite, limonite, doelterite, organic matter. (E.S.S.)

TABLE K.—*continued*.

G.S.M. No. ..	[6360.]	Kc.	Kd.	Ke.	Kf.	Kg.
Rock	Tuff.	Clay.	Clay.	Clay.	Clay.	Clay.
Locality ..	Arrino.	Bellevue.	Belluvue.	Bellevue.	Bellevue.	Bellevue.
SiO ₂	67·56	61·21	63·75	69·94	69·80	60·70
Al ₂ O ₃	9·27	19·55	17·18	13·73	14·45	17·26
Fe ₂ O ₃	3·07	6·73	7·40	6·59	6·31	11·15
FeO	·91	..	..	..	..	..
MnO	·25	..	..	..	..	..
MgO	2·48	·62	·49	·47	·44	·29
CaO	5·75	·15	·13	·11	·06	<i>Nil</i>
Na ₂ O	1·72	..	..	..	..	..
K ₂ O	2·39	..	..	..	..	..
H ₂ O—	·53	..	..	..	..	..
H ₂ O+	1·56	10·44 ⁽¹⁾	10·02 ⁽¹⁾	7·84 ⁽¹⁾	7·84 ⁽¹⁾	10·07 ⁽¹⁾
TiO ₂	·75	..	..	..	..	..
CO ₂	3·37	..	..	..	..	..
P ₂ O ₅	·71	..	..	..	..	..
FeS ₂	·09	..	..	..	..	..
Total	100·44	98·70	98·97	98·68	98·90	99·47
Sp. gr. ..	2·65	..	..	..	..	..
Analyst ..	J.H.B.	E.S.S.	E.S.S.	E.S.S.	H.B.	H.B.
Date	1909	1911	1911	1911	1911	1911

(1) Ignition Loss.

[6360.] Tuff. Carboniferous (?).

Railway Station yard, Arrino, S.W. Div. (H. 50).

Components: Felspars, quartz, calcite, limonite, ilmenite.

(E.S.S.)

Kc-Kg. Bedded Clays. Tertiary or Quaternary.

200 yards N.E. of Railway Station, Bellevue, S.W. Div. (H. 50).

Components: Kaolin (halloysite ?), quartz, limonite, muscovite, tale, organic matter. (E.S.S.)

TABLE K.—*continued.*

G.S.M. No. ..	Kh.	Ki.	Kj.	Kk.	Kl.	Km.
Rock	Clay.	Clay.	Clay.	Clay.	Clay.	Clay.
Locality ..	Bellevue.	Bellevue.	Bellevue.	Bellevue.	Bellevue.	Bellevue.
SiO ₂	56·86	62·08	53·03	64·89	68·24	72·19
Al ₂ O ₃	22·63	18·60	24·69	17·22	14·95	12·09
Fe ₂ O ₃	7·64	6·94	7·71	7·36	7·69	6·14
MgO	·40	·33	·49	·42	·55	·19
CaO	·05	Trace	Trace	Trace	·13	·31
Ignition ..	11·53	10·39	13·13	8·90	8·16	6·75
Total	99·11	98·34	99·05	98·79	99·72	97·67
Analyst ..	H.B.	A.J.R.	A.J.R.	A.J.R.	H.B.	A.J.R.
Date	1911	1911	1911	1911	1911	1911

Kh-Km. Clays, from same locality as, and similar in composition to, those numbered **Kc-Kg**.

TABLE K.—concluded.

G.S.M. No.	Kn.	Kp.	Kq.	Kr.	[2264.]	[2265.]	[Ks.]
Rock ..	Clay.	Shale.	Shale.	Shale.	Shale .	Shale.	Shale.
Locality ..	Bellevue.	Belmont.	Belmont.	Mujar.	New-lands.	New-lands.	Collie.
SiO ₂ ..	71·31	56·80	56·82	61·92	65·45	61·39	51·95
Al ₂ O ₃ ..	14·13	19·88	19·67	26·09	21·53	18·12	29·58
Fe ₂ O ₃ ..	5·26	7·16	7·51	·75	·94	8·74	3·40
FeO ..	..	..	..	..	·12	·12	..
MnO ..	..	..	..	..	·09	·11	..
MgO ..	·47	·41	·50	·27	·71	1·00	1·01
CaO ..	·34	·74	·63	<i>Nil</i>	<i>Nil</i>	Trace	Trace
Na ₂ O ..	..	2·25	..	·26	·31	·40	1·09
K ₂ O ..	..	1·92	..	·74	1·69	1·98	·63
H ₂ O — ..	..	4·34	..	1·48	1·96	2·16	·54
H ₂ O + ..	7·21 ⁽¹⁾	6·63 ⁽¹⁾	10·18 ⁽¹⁾	8·64	7·34	6·38	11·23
TiO ₂ ..	..	..	..	·54	..	..	..
V ₂ O ₃ ..	..	Trace	Trace	Str. tr.	..	..	..
NaCl ..	..	·46	..	..	..	..	..
Total ..	98·72	100·59	95·31	100·69	100·14	100·40	99·43
Analyst ..	A.J.R.	A.J.R.	E.S.S.	D.G.M.	E.S.S.	E.S.S.	E.S.S.
Date. ..	1911.	1911.	1911.	1912.	1906.	1906.	1899.

⁽¹⁾ Ignition loss.

Kn. Clay, from same locality, and of same composition as **Kc-Km.**

Kp. Shale. Lower bed, 5ft. to 7ft. deep.

Kq. Shale. Upper bed, 2ft. to 5ft. deep. Mesozoic or Tertiary.

West Australian Pottery Co's. Pit, west of Racecourse, Belmont Park, S.W. Div., Perth (H. 50).

Components: Kaolin (halloysite ?), quartz, mica, limonite, calcite, organic matter, salt. (E.S.S.)

Kr. Shale. White weathered beds near surface. Carboniferous (?).

Pottery Co's. Pit, Mujar, east of Collie, S.W. Div. (I. 50).

Components: Kaolin, quartz, mica. (E.S.S.)

[2264.] Shale. White bed.

[2265.] Shale. Red bed. Age unknown.

Railway cutting near Newlands, S.W. Div. (I. 50).

Components: Kaolin, quartz, mica, limonite. (E.S.S.)

Ks. Shale (Fireclay). Carboniferous (?).

West Collie Colliery, Collie, S.W. Div. (I. 50).

Components: Kaolin, quartz, mica, organic matter. (E.S.S.)

TABLE L—COALS AND COAL SHALES.

108

No.	Material.	Locality and Seam.	Thickness of Coal.	Date of Sampling.	Specific Gravity.	Caloric Value, B.T.U.	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
La	Bituminous Coal ...	WYNDHAM—KIMBERLEY DIVISION. Band in Bore at 115ft. ...	ft. in. 0 0½	1907	...	...	1.74	42.80	51.52	3.94	...
C4094	Hyd. Bit. Coal	LIVERYNGA—KIMBERLEY DIVISION. Bands in Station Bore at 50ft. ...	0 0½	1909	...	...	11.71	37.81	36.92	13.56	...
B467	Lignite ...	BOOLATHANNA—N.W. DIVISION. Band in Station Bore at 1,700ft. ...	...	1904	1.35	...	15.79	31.71	43.67	8.83	...
C2720	Hydrous Bit. Coal	ERADU—MURCHISON DIVISION. Seam in Bore at 120ft., Top Section	2 0	1907	...	...	8.14	38.08	30.80	22.97	...
C2721	Hyd. Bit. Coal ...	Seam in Bore at 120ft., Bottom Section	2 0	"	...	9,900	9.59	40.28	37.97	12.16	...
C2722	Coal Shale ...	Bed beneath Coal Seam ...	2 0	"	...	...	6.99	30.05	27.06	35.90	...
Lb	Hyd. Bit. Coal ...	UPPER IRWIN RIVER—MURCHISON DIVISION. Outcrop of Seam in River Bank ...	3 0	1888 ?	...	...	17.04	28.61	41.29	13.06	...
Lc	" "	" "	3 0	"	...	...	12.40	32.20	43.50	11.90	0.83
Ld	" "	" "	3 0	"	...	...	15.63	23.06	39.32	21.99	...
C3569	" "	Seam in Tunnel, Top Section ...	1 3	1907	...	7,020	22.04	23.84	37.25	16.87	0.52
C3570	" "	Seam in Tunnel, Middle Section ...	1 9	"	...	7,182	24.74	27.12	31.98	16.16	0.75
C3751	" "	Seam in Tunnel, Bottom Section ...	2 0	"	...	7,965	24.25	26.73	37.97	11.05	1.69
D2430	" "	Seam in Tunnel ...	5 0	1912	...	8,593	18.39	29.87	40.13	11.61	...

A1075	Hyd. Bit. Coal. ...	DONGARRA—S.W. DIVISION.									
	Seam in Bore at 265ft. ...	0	4	1899	...	...	13.13	29.47	49.40	8.00	...
A527	Brown Coal Shale	COOLGARDIE—CENTRAL DIVISION.									
A529	"	...	...	1898	...	...	29.71	12.93	2.04	55.32	...
A624	"	6	0	"	...	...	30.56	23.62	9.45	36.37	...
A700	"	...	...	"	...	...	41.73	19.35	7.84	31.08	...
Le	"	...	...	"	1.493	...	24.24	29.81	5.51	40.44	...
A3984	"	...	...	...	...	...	29.00	18.30	8.31	44.39	...
	Seam in Olsen's Shaft (long exposed to air)	...	...	1902	...	...	16.81	33.12	10.32	39.75	...
A4086	"	...	...	1903	...	...	18.32	23.65	10.57	47.46	...
Lf	Hyd. Bit. Coal. ...	DARDANUP—S.W. DIVISION.									
	Seam in Bore ...	...	...	...	...	...	14.36	35.89	46.14	3.61	...
B1322	Brown Coal	DONNYBROOK—S.W. DIVISION.									
C3441	"	?	...	1905	...	...	14.49	35.51	25.80	24.20	...
C4169	"	Seam on P.A. 155H	...	1909	1.37	5,710	26.95	25.46	21.98	25.61	...
C4170	"	"	...	"	...	6,315	31.34	28.43	24.37	15.86	...
C4171	"	"	...	"	...	6,928	31.28	31.57	26.12	11.03	...
C4302	"	"	...	"	...	6,429	35.00	28.60	24.70	11.70	...
C4303	"	Main Seam, O'Grady's No. 1 Shaft	...	"	...	6,072	36.28	27.67	22.60	13.45	...
	Fault Seam, O'Grady's No. 1 Shaft	...	...	"	...	6,364	33.48	29.12	22.66	14.74	...
M3617	"	CLIFFY HEAD—S.W. DIVISION.									
M3618	"	No information	...	1902	...	...	23.04	40.99	12.50	23.47	...
	"	"	...	"	...	...	23.11	36.62	25.45	14.82	...

TABLE L.—continued.

No.	Material.	Locality and Seam.	Thickness of Coal.	Date of Sampling.	Specific Gravity.	Calorific Value, B.T.U.	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
		NORNALUP INLET, S.W. DIVISION.	ft. in.								
D6057	Brown Coal	No. information	...	1914	...	...	12.89	35.79	32.42	18.90	...
D6058	Brown Coal Shale	Overlying Coal	...	"	...	...	3.73	15.39	5.43	75.45	...
		FLY BROOK—S.W. DIVISION.									
A3721	Hydrous Bit. Coal	Outcrop	...	1902	1.32	...	15.71	38.36	43.33	2.60	...
B1691	"	"	...	1906	...	...	10.75	37.48	30.87	20.90	...
B1692	"	"	...	"	1.35	10,167	13.31	37.42	46.45	2.82	...
[M3454]*	"	Air dried for several years	...	...	1.35	10,098	10.17	42.49	43.73	3.61	0.39
		FITZGERALD RIVER—S.W. DIVISION.									
[M2996]	Brown Coal	No information	...	1901	...	...	22.08	37.32	27.76	12.84	...
D1338	Brown Coal Shale	"	...	1911	...	...	25.84	26.35	15.08	32.73	...
		COLLIE—S.W. DIVISION.									
Lg	Hydrous Bit. Coal	Seam at T17, C.M.L. 30, Outerop	4 0	1890	...	...	11.70	21.83	54.17	9.31	2.99
Lh	"	"	4 0	1895	...	...	13.00	35.15	48.54	3.31	Trace
A215 (1)	"	West Collie Mine, C.M.L. 31, West Collie Seam (2)	5 6	1897	1.211	11,690	10.93	32.86	52.87	3.34	.59
[M718]	"	West Collie Mine, Top Section, West Collie Seam	...	1898	1.327	11,160	12.07	31.75	48.10	8.08	2.00
[M720]	"	West Collie Mine, Bottom Section, West Collie Seam	...	"	1.417	10,090	10.60	26.00	46.85	16.55	.40
[M719]	Coal Shale	West Collie Mine, Middle Section, West Collie Seam	...	"	1.565	6,910	9.10	27.18	33.85	29.87	.10

A715	Hydrous Bit. Coal	West Collie Mine, Single lump ⁽³⁾ , West Collie Seam	...	1 267	11,420	14.57	36.61	44.80	4.02	...
A710	"	"	...	1 319	10,780	13.87	32.62	45.63	7.88	...
A711	"	"	...	1 356	10,250	11.22	29.58	44.89	14.31	...
A712	"	"	...	1 436	10,140	10.73	28.35	45.05	15.87	...
A713	"	"	...	1 448	9,400	10.98	25.58	45.33	18.11	...
A714	"	"	...	1 468	9,200	10.33	25.48	45.63	18.56	...
A716	"	"	...	1 525	...	8.94	29.61	27.57	33.88	.37
D4720	Coal Shale	"	...	1913	...	13.46	27.89	50.17	8.48	...
B3729	Hydrous Bit. Coal	West Collie Mine, West Collie Seam	...	1907	10,540	17.43	32.97	46.59	3.01	.78
B4278	"	Four miles East of Collie ...	...	1909	8,048	16.79	32.75	28.28	22.18	...
B4279	"	Eight miles East of Collie...	...	...	10,631	20.77	36.26	41.65	1.32	...
Li	"	"	...	...	...	15.20	32.46	45.03	5.08	2.23
	"	First sample from river bed, Wall- send Seam	17 0	1889	...	...	...	...	...	...
Lj	"	Government Mine, 100ft., Wallsend Seam	17 0	1895	7,080	14.50	34.69	49.07	1.74	Trace
A665	"	Government Mine, Heap at Surface, Wallsend Seam	17 0	1898	10,770	12.03	25.65	54.78	7.54	0.10
A1090	"	Wallsend Mine, Wallsend Seam	17 0	1899	1 368	15.05	24.95	53.30	6.70	.23
A1091	"	"	17 0	"	1 408	14.17	26.63	52.43	6.77	.19
A1161	"	"	17 0	"	1 405	13.79	27.89	51.18	7.14	.17
A2500	"	Wallsend Mine, 543ft., No. 1 Bore, Wallsend Seam	17 0	1900	1 418	13.10	28.83	50.35	7.72	.31
Lk	"	Proprietary Mine, Wallsend Seam	17 0	1904	...	12.73	24.03	55.13	7.64	.47
B618	"	"	17 0	1905	...	14.36	27.03	51.64	6.66	.31
B625	"	Co-operative Mine, Wallsend Seam	17 0	"	10,098	15.41	28.65	48.48	6.39	1.07
B715	"	"	17 0	"	...	10.88	23.60	52.86	10.73	1.93

* Ultimate analysis: C, 58.30; H, 4.52; O, 22.45; N, 0.56; S, 0.39; moisture, 10.17; ash, 3.61. (1) Air dried for six months.

(2) The relative geological order of the seams worked at Collie is: West Collie (oldest), Wallsend, Proprietary, Collietburn 2, Collietburn 1, Boulder, Cardiff 1 (newest).

(3) Depth 120 ft.

TABLE L.—COALS AND COAL SHALES—continued.

No.	Material.	Locality and Seam.	Thickness of Coal.	Date of Sampling.	Specific Gravity.	Calorific Value. B.T.U.	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
C771	Hydrous Bit. Coal	COLLIE—continued. Co-operative Mine, 230ft., Wallsend Seam	ft. in. 17 0	1908	..	9,990	18.18	24.83	52.35	4.64	..
C3263	"	"	17 0	1909	..	10,644	11.73	27.14	51.20	9.93	..
D4457	"	Co-operative Mine, Bright Coal, Wallsend Seam	17 0	1913	..	..	11.52	27.97	53.26	7.25	..
D4458	"	Co-operative Mine, Dull Coal, Walls- end Seam	17 0	"	..	..	11.41	23.91	54.78	9.90	..
A669	"	Proprietary Mine, Proprietary Seam	..	1898	1.409	9,770	13.98	25.82	53.51	6.69	.05
A2498	"	Wallsend Bore, 471ft., Proprietary No. 1 Seam	8 0	1900	1.415	9,940	12.76	27.14	49.40	10.70	.33
A2499	"	Wallsend Bore, 498ft., Proprietary No. 2 Seam	7 2	"	1.428	10,230	12.81	30.07	47.59	9.53	.30
A2501	"	Wallsend Bore, 634ft., Seam below Wallsend	4 6	1900	1.369	11,560	12.93	29.30	51.44	6.33	.59
A2497	"	Wallsend Bore, 250ft., Seam above Proprietary	3 6	"	1.412	10,230	12.89	31.58	43.37	12.16	.39
L1	"	Scottish Colliery, Collieburn No. 2 Seam	6 0	1903	..	..	14.0	23.9	59.5	2.6	..
B2531	"	Scottish Colliery, Collieburn No. 1 Seam	8 0	1905	..	..	15.72	30.00	49.51	4.17	.60
B619	"	"	8 0	"	..	..	14.20	35.75	46.88	2.81	.36
Lm	"	Cardiff Colliery, Boulder Seam ..	7 4	1903	..	..	18.8	28.2	46.6	6.4	..

B2414	"	Cardiff Colliery, Cardiff No. 1 Seam	12	2	1904	..	..	15.81	27.07	51.19	5.44	.49
B2442	"	"	12	2	"	..	..	14.41	31.58	46.68	6.05	1.28
B620	"	"	12	2	"	..	..	18.28	31.95	44.50	5.04	.23
B717	"	"	12	2	1905	..	..	17.96	33.59	40.27	6.31	1.87
C707 ⁽¹⁾	"	Proprietary Mine, C.M.L. 89, Walls- end Seam ?	7	0	1908	1.381	9,333	19.52	25.02	46.38	9.08	.59
C569	"	Co-operative Mine, C.M.L. 104, Walls- end Seam	10	0	"	1.403	10,058	17.73	24.56	50.57	7.14	.30
C538	"	Scottish Colliery, C.M.L. 183, Collie- burn, No. 1 Seam	8	6	"	1.322	10,264	22.43	33.45	40.40	3.72	.58
C2367	"	"	8	6	"	1.286	9,828	23.72	33.52	40.24	2.52	.54
C2227	"	Cardiff Colliery, C.M.L. 201, Boulder Seam	7	0	"	1.328	9,170	23.70	31.55	39.64	5.11	.69
C708	"	Cardiff Colliery, C.M.L. 201, Cardiff No. 1 Seam	6	0	"	1.314	9,631	22.52	30.38	41.65	5.45	.50
C2492	"	"	6	0	"	1.329	9,307	23.83	32.58	39.65	3.94	.50

⁽¹⁾ Samples from C 707 to end of table form a special series which were put in hermetically sealed tins at the working face in order to avoid evaporation of moisture before analysis. All other coals in this table were more or less air dry before analysis. Ultimate analyses of the coals in this series will be found on the following page. See G.S. W.A. Bull. 48, pp. 66-78.

TABLE L.—*concluded.*

No.	..	C707.	C569.	C568.	C2367.	C2227.	C708.	C2492.
Mine	..	Pro- prietary.	Co-oper- ative.	Scottish.	Scottish.	Cardiff.	Cardiff.	Cardiff.
Seam	..	Wallsend. (?)	Wallsend.	Collie- burn I.	Collie- burn I.	Boulder.	Cardiff I.	Cardiff I.

ULTIMATE ANALYSES OF COALS.

Carbon	..	55·53	59·33	54·25	54·43	52·75	52·77	52·53
Hydrogen	..	3·04	3·25	3·68	3·81	3·49	3·52	3·42
Oxygen	..	11·25	11·11	14·34	13·84	13·07	14·35	14·66
Nitrogen	..	·99	1·14	1·00	1·14	1·19	·89	1·12
Sulphur	..	·59	·30	·58	·54	·69	·50	·50
Ash	..	9·08	7·14	3·72	2·52	5·11	5·45	3·94
Moisture	..	19·52	17·73	22·43	23·72	23·70	22·52	23·83

ANALYSES OF ASHES.

SiO ₂	..	35·29	61·18	28·20	22·73	45·49	51·36	36·04
Al ₂ O ₃	..	16·59	27·63	24·58	29·02	25·59	13·58	27·35
Fe ₂ O ₃ ⁽¹⁾	..	36·57	5·67	23·38	25·85	18·93	13·33	19·95
Mn ₃ O ₄	..	1·35	·43	Trace	·86	None	·29	·77
MgO	..	2·18	·51	3·99	2·98	2·59	2·76	3·70
CaO	..	2·94	1·61	5·39	5·69	3·29	2·92	4·51
Na ₂ O	..	·39	·72	·80	·99	·76	·43	·94
K ₂ O	..	·18	·20	·32	·12	·07	·23	·27
TiO ₂	..	1·38	1·66	1·75	1·71	1·14	·83	1·08
P ₂ O ₅	..	·16	Trace	8·31	8·71	1·72	2·92	3·79
SO ₃	..	2·43	·58	3·30	1·09	·94	1·43	1·70
V ₂ O ₅	..	·21	·10	·02	Trace	·05	·07	·04
Total	..	99·67	100·29	100·04	99·75	100·57	100·18	100·14

(¹) In the unburnt coal the iron exists for the most part as ferrous carbonate.

TABLE M.—GRAPHITE ROCKS.

No.	B2153.	[M6064.]	[M6065.]	B1620.	[M6639.]	D8228.
Rock	Graphite Schist.	Graphitic Ironstone.	Graphitic Ironstone.	Graphitic Ironstone.	Graphitic Ironstone.	Graphitic Ironstone.
Locality . . .	Bulong.	North-ampton. 10m. S.E.	North-ampton. 2½m. S.E.	North-ampton.	North-ampton.	North-ampton.
Moisture . . .	3·30	·39	1·08	·58	·72	·66
Combined Water and Volatile	8·74	4·82	7·10	3·46	6·34	4·62
Graphite . . .	1·37	68·92	12·41	49·98	56·72	36·82
Ash	86·59	25·87	79·41	45·98	36·22	57·90
Variety of Graphite	Amorphous.	Flake	Flake	Flake	Flake	Flake
Date	1906	1905	1905	1906	1906	1915

No.	[C4375.]	[C4412.]	[M6132.]	[M6133.]	[M6134.]	[M6135.]
Rock	Graphitic Schist.	Graphitic Schist.	Graphitic Schist.	Graphitic Schist.	Graphitic Schist.	Graphitic Schist.
Locality . . .	Kirrup.	Kirrup.	Donnelly River. ⁽¹⁾	Donnelly River.	Donnelly River.	Donnelly River.
Moisture . . .	·56	·26	3·14	1·68	2·06	2·42
Combined Water and Volatile	23·58	23·64	8·42	8·66	7·56	8·88
Graphite . . .	17·66	13·40	52·80	53·20	50·78	50·64
Ash	58·20	62·70	35·64	36·46	37·08	37·92
Variety of Graphite	Amorphous.	Amorphous.	Flake and Amorphous.	Flake and Amorphous.	Flake and Amorphous.	Flake and Amorphous.
Date	1909	1909	1905	1905	1905	1905

(¹) The graphite deposit on the Donnelly River is 12 miles due West of Manjimup Railway Station.

TABLE M.—*continued.*

No.	[M6136.]	[M6137.]	B970.	B962.	B963.	[M6066.]
Rock	Graphitic Schist.	Graphitic Schist.	Graphitic Clay (1)	Graphitic Clay.	Graphitic Clay.	Graphitic Clay.
Locality	Donnelly River.	Donnelly River.	Donnelly River.	Donnelly River.	Donnelly River.	Donnelly River.
Moisture	·48	2·28	·40	4·90	5·36	7·16
Combined Water and Volatile	8·04	9·82	7·52	9·12	4·24	5·77
Graphite	50·64	28·84	47·84	31·32	39·96	32·48
Ash	40·84	59·06	44·24	54·66	50·44	54·59
Variety of Graphite	Flake and Amorphous.	Flake and Amorphous.	Amorphous.	Amorphous.	Amorphous.	Amorphous.
Date	1905	1905	1905	1905	1905	1905

(1) Probably a completely weathered chlorite schist or slate.

No.	B1188.	B1189.	B1190.	D8110.	D8111.	D8112.
Rock	Graphitic Clay.	Graphitic Clay.	Graphitic Clay.	Graphitic Clay.	Graphitic Clay.	Graphitic Clay.
Locality	Donnelly River.	Donnelly River.	Donnelly River.	Donnelly River.	Donnelly River.	Donnelly River.
Moisture	·94	·90	·94	4·63	7·75	9·07
Combined Water and Volatile	4·18	4·42	5·78	9·18	10·36	8·53
Graphite	38·74	41·86	36·74	26·98	30·12	32·02
Ash	56·14	52·82	56·54	59·21	51·77	50·38
Variety of Graphite	Amorphous.	Amorphous.	Amorphous.	Amorphous.	Amorphous.	Amorphous.
Date	1905	1905	1905	1915	1915	1915

TABLE M.—concluded.

No.	D8113.	D8114.	[M3124.]	B1.	[M6063.]	B46.
Rock	Graphitic Clay.	Graphitic Clay.	Graphitic Clay.	Graphitic Clay.	Graphitic Clay.	Graphitic Clay.
Locality ..	Donnelly River.	Donnelly River.	Donnelly River.	Donnelly River.	Donnelly River.	Donnelly River.
Moisture ..	6·49	11·45	1·32	1·57	1·41	·78
Combined water	6·68	8·68	10·26	8·97	7·07	7·10
Volatile						
Graphite ..	23·36	28·20	23·50	26·03	20·66	30·50
Ash	63·47	51·07	64·92	63·43	70·86	61·62
Variety of Graphite	Amorphous.	Amorphous.	Amorphous.	Amorphous.	Amorphous.	Amorphous.
Date	1915	1915	1901	1904	1905	1905

No.	D4041.	D4177.	D4896.	D9252.	D9253.
Rock	Graphitic Clay. (1)	Graphitic Clay.	Graphitic Clay.	Graphitic Clay.	Graphitic Clay.
Locality ..	Kendenup.	Kendenup.	Kendenup.	Kendenup.	Kendenup.
Moisture ..	} 5·60	6·40	16·30	{ 2·96	4·24
Combined Water and Volatile					
Graphite ..					
Ash	40·20	49·30	1·02	3·94	2·11
Variety of Graphite	54·20	49·30	83·98	46·24	26·86
	Flake	Flake	Flake	46·86	66·79
				Flake	Flake
Date	1913	1913	1913	1916	1916

(1) Much weathered chlorite schist or slate.

TABLE N.—LATERITES.

G.S.M. No. ..	Na.	[13002.]	[13003.]	[13004.]	[13005.]	[6300.]
Rock	Laterite.	Laterite.	Laterised Granite.	Norite.	Laterite.	Laterite.
Locality ..	Boogardie.	Ora Banda.	Ora Banda.	Ora Banda.	Ora Banda.	Comet Vale.
SiO ₂	11·46	36·83 ⁽¹⁾	45·55	54·26	3·49 ⁽²⁾	3·14
Al ₂ O ₃	..	8·48	9·71	1·75	16·44	..
Fe ₂ O ₃	73·81	45·67	35·39	3·53	60·61	79·01
FeO	..	..	·10	6·93	..	..
MnO	..	<i>Nil</i>	<i>Nil</i>	·39	..	..
MnO ₂	..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	·29	..
MgO	..	Trace	<i>Nil</i>	26·23	·28	..
CaO	..	<i>Nil</i>	·32	2·24	<i>Nil</i>	..
Na ₂ O	..	..	·16	·38	..	..
K ₂ O	..	..	·28	·24	..	..
H ₂ O—	·19	} 9·32	{ ·86	1·01	} 16·60	..
H ₂ O+	2·67			1·68		
TiO ₂	..	·06	<i>Nil</i>	·18	1·34	..
CO ₂	..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	..
P ₂ O ₅	·05	·05	·17	·56	·07	·18
SO ₃	·21	..	·25	·07	..	·30
Cr ₂ O ₃	..	Trace	<i>Nil</i>	·40	·96	5·30
V ₂ O ₅	..	·06	·01	·14	·10	..
Total	..	100·47	100·80	99·99	100·18	..
Sp. gr.	..	..	2·71	..	..	..
Analyst	E.S.S.	D.G.M.	A.J.R.	H.B.	D.G.M.	E.S.S.
Date	1903	1913	1913	1913	1913	1905

(1) Combined silica, 8·09 %

(2) Combined silica, 3·16 %.

[Na.] Turgite Laterite.

Boogardie, Mur. Div. (G. 50).

Components: Turgite, quartz, diaspore, halloysite. (E.S.S.)

[13002.] Limonite Laterite.

Near Enterprise Leases, Ora Banda, Cen. Div. (H. 51).

Components: Limonite, quartz, bauxite, halloysite. (E.S.S.)

[13003.] Laterised Granite, *i.e.*, much weathered granite impregnated with secondary hydrates of iron and aluminium.

Near Enterprise Leases, Ora Banda, Cen. Div. (H. 51).

Components: Limonite, quartz, kaolin (halloysite ?), gibbsite (?), feldspars. (E.S.S.)

[13004.] Much weathered norite underlying laterite No. 13005.

West of Black Flag Road, Ora Banda, Cen. Div. (H. 51).

Components: Hypersthene, feldspars, kaolin, serpentine, etc. (E.S.S.)

[13005.] Limonite Laterite, derived from 13004.

West of Black Flag Road, Ora Banda, Cen. Div. (H. 51).

Components: Limonite, bauxite, halloysite, doelterite ⁽¹⁾. (E.S.S.)

[6300.] Turgite Laterite.

Comet Vale, Cen. Div. (H. 51).

Components: Turgite, chromium hydrate, halloysite, quartz. (E.S.S.)

⁽¹⁾ Native metatitanic acid (Lacroix).

TABLE N.—*continued.*

G.S.M. No. ..	[2119.]	[2907.]	[2991.]	[3282.]	[551.]
Rock	Laterite.	Laterite.	Laterite.	Laterite.	Laterite.
Locality ..	Kalgoorlie.	Kalgoorlie.	Kalgoorlie.	Kalgoorlie.	Coolgardie.
SiO ₂	2·73	1·77	2·52	2·67	2·53 ¹⁾
Al ₂ O ₃	12·76	12·29	5·97	9·92	4·32
Fe ₂ O ₃	62·67	75·41	79·41	78·38	80·02
MnO ₂	·35	·41	·07	·07	·13
MgO	·99	<i>Nil</i>	1·56	·35	Trace
CaO	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
H ₂ O	14·46	7·05	6·89	6·00	7·06
TiO ₂	6·00	2·55	3·10	2·01	6·06
P ₂ O ₅	Trace	Trace	Trace	Trace	Trace
Cr ₂ O ₃	·08	·05	·60	·01	·08
V ₂ O ₅	·15	·45	·65	·40	·55
Total	100·19	99·98	100·77	99·81	100·75
Analyst ..	E.S.S.	E.S.S.	E.S.S.	E.S.S.	E.S.S.
Date	1910	1910	1910	1910	1912

(1) Combined silica, 1·77%.

[2119.] Limonite Laterite.

Eureka Extended G.M.L. 1275E, Kalgoorlie, Cen. Div. (H. 51).

Components: Limonite, bauxite (?), halloysite, doelterite.
(E.S.S.)

Reference: B. 42, p. 121.

[2907.] Turgite Laterite.

Mt. Ferrum G.M.L., Williamstown, Kalgoorlie, Cen. Div.
(H. 51).

Components: Turgite, diaspora, doelterite, halloysite. (E.S.S.)

Reference: B. 42, p. 120.

[2991.] Turgite Laterite.

Thunderbolt G.M.L. 1121, Kalgoorlie, Cen. Div. (H. 51).

Components: Turgite, diaspora, haematite, doelterite, halloysite. (E.S.S.)

Reference: B. 42, p. 102.

[3282.] Turgite Laterite.

King Orry G.M.L., Kalgoorlie, Cen. Div. (H. 51).

Components: Turgite, diaspora, haematite, doelterite, halloysite. (E.S.S.)

Reference: B. 42, p. 120.

[551.] Turgite Laterite.

N.E. of White Prince G.M.L. 2892, Coolgardie, Cen. Div.
(H. 51).

Components: Turgite, diaspora, bauxite (?), halloysite, quartz, doelterite. (E.S.S.)

TABLE N.—*concluded.*

G.S.M. No. ..	[997.]	[1096.]	[3148.]	Nb.	Nc.	Nd.
Rock	Laterite.	Laterite.	Laterite.	Laterite.	Laterite.	Laterite.
Locality ..	Wongan Hills.	Baker's Hill.	Smith's Mill.	Smith's Mill.	Smith's Mill.	Gooseberry Hill.
SiO ₂	5·96	13·74	17·17 ⁽¹⁾	36·23 ⁽²⁾	16·05 ⁽³⁾	6·41 ⁽⁴⁾
Al ₂ O ₃	44·66	31·14	46·70	36·48	50·68	36·74
Fe ₂ O ₃	19·08	35·54	10·02	10·70	7·14	39·80
MnO ₂	..	..	..	..	..	·06
MgO	Trace	Trace	Trace	..	..	·15
CaO	Trace	·16	Trace	..	..	·10
H ₂ O—	·58	·69	·58	..	..	1·20
H ₂ O+	26·44	14·71	24·79	[16·22]	25·95	13·73
TiO ₂	3·10	4·33	·59	·37	·62	1·98
SO ₃	·18	..	..	..	..	..
P ₂ O ₅	Trace	Trace	Trace	..	..	Trace
Cr ₂ O ₃	..	..	..	..	..	·03
V ₂ O ₅	..	..	..	..	..	·23
Total	100·00	100·31	99·95	100·00	100·44	100·43
Sp. gr.	..	..	2·44	..	..	..
Analyst	E.S.S.	E.S.S.	E.S.S.	M.A.B.	H.B.	E.S.S.
Date	1901	1901	1901	1912	1912	1912

¹ Mostly quartz.² Combined silica, 12·40%.³ Combined silica, 11·05%.⁴ Combined silica, 1·97%.

[997.] Gibbsite Laterite.

Wongan Hills, S.W. Div. (H. 50).

Components: Gibbsite, limonite, halloysite, quartz, doelterite.
(E.S.S.)

[1096.] Laterite.

Baker's Hill, S.W. Div. (H. 50).

Components: Goethite (?), bauxite (?), quartz, halloysite, doelterite. (E.S.S.)

[3148.] Gibbsite Laterite.

Five chains S.W. of Railway Station, Smith's Mill (Glen Forrest), S.W. Div. (H. 50).

Components: Gibbsite, limonite, quartz, halloysite, doelterite.
(E.S.S.)

Nb. Gibbsite-halloysite Laterite.

Smith's Mill, S.W. Div. (H. 50).

Components: Gibbsite, halloysite, quartz, limonite. (E.S.S.)

Nc. Gibbsite Laterite.

Smith's Mill, S.W. Div. (H. 50).

Components: Gibbsite, halloysite, limonite, quartz, doelterite.
(E.S.S.)

Nd. Turgite-bauxite Laterite.

Gooseberry Hill, S.W. Div. (H. 50).

Components: Turgite, bauxite (?), quartz, halloysite, doelterite. (E.S.S.)

TABLE O.—HAEMATITE-QUARTZ ROCKS.

G.S.M. No. ..	Oa.	Ob.	[7729.]	[7753.]	[342.]	[338.]
Rock	Haema- tite Rock.	Haema- tite Rock.	Haema- tite Rock.	Haema- tite Quartzite.	Haema- tite Rock.	Haema- tite Rock.
Locality ..	Yampi Island.	Yampi Island.	Mt. Edith.	Mt. Stuart.	Mt. Hale.	Mt. Narryer.
SiO ₂	4·16	7·06	1·70	40·21	3·14	9·33
Al ₂ O ₃	..	..	·28	1·80	·94	·60
Fe ₂ O ₃	94·88	92·67	96·73	54·75	92·62	81·91
FeO	..	..	·90	..	·97	Trace
MnO	..	..	·03	·14	·50	Trace
MgO	..	..	·14	·33	·55	<i>Nil</i>
CaO	..	..	·12	·23	·11	3·32
Na ₂ O	..	..	..	·52	..	..
K ₂ O	..	..	..	·39	..	..
H ₂ O—	·08	·08	·06	·05	} 1·08	4·82
H ₂ O+	·12	·08	·57	·97		
TiO ₂	Trace	Trace	·06	<i>Nil</i>	1·09	·53
CO ₂	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
P ₂ O ₅	·14	·03	·06	·24	·17	Trace
FeS ₂	·13	·07	·04	·09	·07	·24
Total	99·51	99·99	100·69	99·72	101·24	100·76
Sp. gr.	..	..	4·93	3·58	..	..
Analyst	E.S.S.	E.S.S.	E.S.S.	C.C.W.	F. S. Earp	F. S. Earp
Date	1908	1908	1907	1908	1901	1901

Oa. Haematite rock, iron lode.

Main lode, centre of island, Yampi (Koolan) Island, Kim. Div. (E. 51).

Components: Haematite, quartz. (E.S.S.)

Ob. Haematite rock, iron lode.

East end of island, Yampi Island, Kim. Div. (E. 51).

Components: Haematite, quartz. (E.S.S.)

[7729.] Haematite rock, iron lode.

Mt. Edith, Upper Ashburton River, N.W. Div. (F. 50).

Components: Haematite, quartz, magnetite, limonite. (E.S.S.)

Reference: B. 33, p. 59.

[7756.] Banded Haematite-quartzite.

Mt. Stuart, Upper Ashburton River, N.W. Div. (F. 50).

Components: Haematite, quartz, limonite, magnetite. (J.A.T.)

Reference: B. 33, p. 173.

[342.] Haematite rock, iron lode.

Mt. Hale, Mur. Div. (G. 50).

Components: Haematite, quartz, magnetite, limonite. (E.S.S.)

[338.] Haematite rock, iron lode.

Mt. Narryer, Mur. Div. (G. 50).

Components: Haematite, quartz, limonite. (E.S.S.)

TABLE O.—*continued*.

G.S.M. No. ..	Oc.	[11873.]	[4401.]	[4402.]	[4403.]	[4404.]
Rock	Jasper.	Haema- tite rock.	Haema- tite quartzite.	Haema- tite quartzite.	Haema- tite quartzite.	Haema- tite quartzite.
Locality ..	Sand- stone.	Mt. Mason.	Edjudina.	Edjudina.	Edjudina.	Edjudina.
SiO ₂	56·45	·74	45·05	60·82	59·55	51·76
Al ₂ O ₃	4·37	·82	..	..	..	..
Fe ₂ O ₃	30·81	96·88	53·36	36·90	38·07	47·75
FeO	<i>Nil</i>	..	<i>Nil</i>	<i>Nil</i>	Present	..
MnO	..	·22	..	..	..	..
MgO	<i>Nil</i>	Trace	..	..	..	..
CaO	·54	Trace	..	..	..	..
Na ₂ O	·62	..	..	..	..	..
K ₂ O	·18	..	..	..	..	..
H ₂ O—	·98	·12	·17	·12	·05	·11
H ₂ O+	5·87	1·40	·49	·87	·74	1·08
TiO ₂	..	<i>Nil</i>	..	..	..	..
CO ₂	<i>Nil</i>	..	..	..	..	..
P ₂ O ₅	..	·22	·10	·14	·08	·10
FeS ₂	..	·15	·06	·05	·08	·06
Carbon	·26 ⁽¹⁾	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
Total	100·08	100·58	99·23	98·90	98·57	100·86
Sp. gr. ..	..	..	..	..	..	..
Analyst ..	H.B.	D.G.M.	E.S.S.	E.S.S.	E.S.S.	E.S.S.
Date	1913	1912	1903	1903	1903	1903

¹ Present as an organic compound, not as graphite.

Oc. Jasper.

Shaft W. of main shaft, Black Range West G.M.L., Sandstone,
Cen. Div. (H. 50).

Components: Quartz, haematite, limonite, albite. (E.S.S.)

Reference: B. 62, pp. 29, 30.

[11873.] Haematite rock, iron lode.

Mt. Mason, S.W. of Mt. Ida, Cen. Div. (H. 51).

Components: Haematite, quartz, limonite. (E.S.S.)

Reference: B. 45, p. 30.

[4401, 4402, 4404.] Banded haematite-quartzite.

Yabboo Hills, Edjudina, Cen. Div. (H. 51).

Components: Quartz, haematite, limonite. (E.S.S.)

Reference: B. 11, p. 15.

[4403.] Banded haematite-quartzite.

Yabboo Hills, Edjudina, Cen. Div. (H. 51).

Components: Quartz, haematite, magnetite, limonite. (E.S.S.)

Reference: B. 11, p. 15.

TABLE O.—*continued.*

G.S.M. No. ..	[4406.]	[4408.]	[11633.]	[1/51.]	[11546.]	[11548.]
Rock	Haema- tite quartzite.	Haema- tite quartzite.	Haema- tite quartzite.	Haema- tite rock.	Haema- tite quartzite.	Haema- tite quartzite.
Locality ..	Edjudina.	Edjudina.	Hogan's Find.	Koolya- nobbing.	Southern Cross.	Southern Cross.
SiO ₂	43·10	61·19	55·44	1·04	51·26	47·42
Al ₂ O ₃	..	..	12·95	..	·52	·43
Fe ₂ O ₃	54·73	32·54	20·14	98·75	45·37	49·27
FeO	<i>Nil</i>	<i>Nil</i>	·84	<i>Nil</i>	1·13	·51
MnO	..	..	..	..	Trace	<i>Nil</i>
MgO	..	..	3·42	..	·30	·37
CaO	..	..	Trace	..	<i>Nil</i>	<i>Nil</i>
Na ₂ O	..	..	1·61	..	·12	·14
K ₂ O	..	..	·11	..	·06	·11
H ₂ O—	·12	·23	·24	} ·39	{ ·20	·78
H ₂ O+	·93	4·24	1·57			·59
TiO ₂	..	..	..	..	Trace	<i>Nil</i>
CO ₂	<i>Nil</i>	<i>Nil</i>	Trace	..	·08	Trace
P ₂ O ₅	·15	·20	..	·04	·07	·41
B ₂ O ₃	<i>Nil</i>	<i>Nil</i>	3·80	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
FeS ₂	·05	·07	..	Trace	·07	Trace
Total	99·08	98·47	100·12	100·22	100·66	100·03
Sp. gr. ..	..	..	..	..	3·25	3·42
Analyst ..	E.S.S.	E.S.S.	A.J.R.	D.G.M.	H.B.	A.J.R.
Date	1903	1903	1912	1915	1911	1912

[4406, 4408.] Banded haematite-quartzite.

Yabboo Hills, Edjudina, Cen. Div. (H. 51).

Components: Quartz, haematite, limonite. (E.S.S.)

[11633.] Banded haematite-quartzite.

Hogan's Find, Cen. Div. (H. 51).

Components: Quartz, haematite, tourmaline, limonite. (R.A.F.)

Reference: B. 53, p. 73.

[1/51.] Haematite rock, Iron lode.

Koolyanobbing Range, Cen. Div. (H. 50).

Components: Haematite, quartz. (E.S.S.)

[11546.] Banded haematite-quartzite.

Centre of Frazer's West G.M.L. 882, Southern Cross, Cen. Div. (H. 50).

Components: Quartz, haematite, hornblende, magnetite, limonite. (E.S.S.)

Reference: B. 49, pp. 98-100.

[11548.] Banded haematite-quartzite.

Close to south boundary of Lord Cardigan G.M.L. 613, Southern Cross, Cen. Div. (H. 50).

Components: Quartz, haematite, hornblende, magnetite. (E.S.S.)

TABLE O.—*concluded.*

G.S.M. No. 	[11554.]	[11557.]	[11558.]	[5957.]
Rock 	Magnetite quartzite.	Haematite quartzite.	Haematite quartzite.	Haematite quartzite.
Locality 	Southern Cross.	Southern Cross.	Southern Cross.	Norseman.
SiO ₂	77·94	53·01	44·81	11·31
Al ₂ O ₃	·24	1·12	·04	3·84
Fe ₂ O ₃	9·47	33·29	50·00	76·31
FeO 	7·72	8·36	2·83	2·16
MnO 	·39	·22	<i>Nil</i>	Trace
MgO 	1·91	2·49	1·02	·33
CaO 	1·17	·67	·29	Trace
Na ₂ O 	·04	·19	Trace	Trace
K ₂ O 	·10	<i>Nil</i>	Trace	Trace
H ₂ O — 	·20	·41	·19	·85
H ₂ O + ...	·41	·31	·48	4·55
TiO ₂	<i>Nil</i>	<i>Nil</i>	Trace	<i>Nil</i>
CO ₂	·79	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
P ₂ O ₅	·09	·44	·18	·06
FeS ₂	·04	·30	·71	·20
Carbon 	<i>Nil</i>	<i>Nil</i>	·06	<i>Nil</i>
Total 	100·51	100·81	100·61	99·61
Sp. gr. 	..	..	..	3·95
Analyst 	H.B.	A.J.R.	H.B.	Synnott
Date 	1911.	1911.	1912.	1905.

[11554.] Banded magnetite-quartzite.

Shaft near centre of Wimmera South G.M.L. 647, Southern Cross, Cen. Div. (H. 50).

Components: Quartz, hornblende, magnetite, chlorite, limonite. (R.A.F.)

Reference: B. 49, pp. 99-100.

[11557, 11558.] Banded haematite-quartzite.

Haddon Consolidated G.M.L. 2342, Southern Cross, Cen. Div. (H. 50).

Components: Quartz, haematite, magnetite, hornblende. (R.A.F.) Also graphite in 11558.

Reference: B. 49, pp. 99-100

[5957.] Banded haematite-quartzite.

Open cut, Hit or Miss G.M.L. 863, Norseman, Euc. Div. (I. 51).

Components: Haematite, quartz, limonite, magnetite. (E.S.S.)

Part II.
METEORITES.

PART II.

ANALYSES OF METEORITES FOUND IN WESTERN AUSTRALIA.

Neglecting as of unknown origin the many thousands of "Australites" or "Obsidianites" which have been discovered on the surface of the central plateau of the State, only twelve undoubted meteorites have been found, all of which are siderites (wholly metallic meteorites), with octahedral structure. These have ranged in size from the two Premier Downs irons, weighing each only four ounces, up to the Youndegin iron, one fragment of which, now in the Vienna Museum, weighs 18 hundredweight. Analyses of all but one ⁽¹⁾ of them have been made in the Survey Laboratory and the results are given in the accompanying Table.

In referring to them it should be remembered that owing to the extremely irregular distribution of the troilite (iron nickel sulphide), cohenite (iron nickel carbide) and graphite, the figures for sulphur, combined carbon and free carbon are only by the merest chance representative and often far from the average. Thus analyses of two small fragments of Mount Edith I. gave *nil* and 0.005 per cent. for the sulphur contents, but a slice cut right through the meteorite shows many large nodules of troilite equal to at least one per cent. of sulphur in the whole body.

⁽¹⁾ Mount Magnet, reported 1916.

TABLE P.—METEORITES.

Name. . . .	Youndegin.	Youndegin.	Ballinoo.	Mt. Stirling.	Mooranoppin
Class	Og.	Og, Ogg.	Off.	Og.	Ogg.
Date of Discovery	1884.	1884.	1892.	1892.	1893.
Fe	92·67	91·67	89·909	92·08	90·82
Ni	6·46	7·01	8·850	6·72	7·21
Co	·55	·93	·740	·81	·88
Cu	Trace	·02	Trace	<i>Nil</i>	<i>Nil</i>
Mn	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
Mg	·42	<i>Nil</i>	<i>Nil</i>	<i>Nil</i> ⁽¹⁾	<i>Nil</i>
P	·24	·30	·501	·17	·42
S	<i>Nil</i>	Trace	Trace	·06	<i>Nil</i>
C Combined . .	<i>Nil</i>	·15	} Trace	·24	·67
C Free	·04	<i>Nil</i>			
Si	<i>Nil</i>	·01	Trace	·01	·01
Total	100·38	100·09	100·00	100·09	100·01
Sp. gr. . . .	7·72-7·86	..	7·8	..	..
Analyst	L. Fletcher.	H.B.	Mariner & Hoskins.	H.B.	H.B.
Date	1887.	1913.	1898.	1915.	1913.

(1) Also Zn, Ca, Cl, O, *Nil*.

Youndegin. (Synonym, Penkarring).

Several fragments, largest 2,044lbs., total about 2,500lbs.

Components: Kamacite, taenite, cohenite, schreibersite, and traces of troilite, graphite, and cliftonite. (Fletcher and E.S.S.)

Principal Reference: Mineralogical Magazine, VIII., 121 (Fletcher).

Ballinoo. (Mt. Erin.)

One fragment, weight 93lbs.

Components: Kamacite, taenite, schreibersite, troilite, augite (?). (Ward.)

Principal Reference: American Journal of Science, V., p. 136 (Ward).

Mount Stirling.

Two fragments, larger 200 lbs., total 201 lbs.

Components: Kamacite, taenite, cohenite, schreibersite. (E.E.S.)

Principal Reference: Records of the Australian Museum, Sydney, III., pp. 58-131 (Cooksey).

Mooranoppin.

One fragment, 2½lbs.

Components: Kamacite, taenite, cohenite, schreibersite. (E.S.S.)

Principal Reference: American Journal of Science, 4, V., p. 140 (Ward).

TABLE P.—*continued.*

Name	Hamersley.	Nuleri.	Mt. Dooling.	Premier Downs I.	Premier Downs II.
Class.	Om.	Om.	Om.-Og.	Om.	Om.
Date of Discovery.	1894.	1902.	1909.	1911.	1911.
Fe	90·914	[93·57]	93·17	91·68	88·51
Ni	8·330	5·79	5·96	7·46	7·58
Co	·590	·41	·64	·64	·89
Cu	<i>Nil</i>	Trace	·02	Trace	·13
Mn	Trace	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
Mg	<i>Nil</i>	·09	Trace	Trace	<i>Nil</i>
P	1·156	·13	·27	·21	·31
S	Trace	Trace	·09	·04	<i>Nil</i>
C Combined ..	} Trace {	·01	·10	·04	1·41
C Free		<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	1·06
Si		<i>Nil</i>	Trace	·01	<i>Nil</i>
Cl		Trace	Trace	<i>Nil</i>	..
Total	100·00	100·00	100·25	100·08	99·89
Sp. gr.	7·78	7·79	..	..	..
Analyst	Mariner & Hoskins.	E.S.S.	E.S.S.	E.S.S.	H.B.
Date	1898.	1907.	1912.	1912.	1913.

Hamersley. (Roebourne).

One fragment, weight 191½lbs.

Components: Kamacite, taenite, schreibersite. (Ward.)

Principal Reference: American Journal of Science, 4, V., p. 136 (Ward).

Nuléri.

One fragment, weight 4ozs.

Components: Kamacite, taenite schreibersite. (E.S.S.)

Principal Reference: W.A. Geol. Survey Bulletin 26, p. 24 (Simpson).

Mount Dooling.

One fragment, weight 69lbs.

Components: Kamacite, taenite, schreibersite, troilite, (E.S.S.)

Principal Reference: W.A. Geol. Survey Bulletin 48, p. 83 (Simpson).

Premier Downs I.

One fragment, weight 4ozs.

Components: Kamacite, taenite, troilite, schreibersite. (E.S.S.)

Principal Reference: W.A. Geol. Survey Bulletin 48, p. 87 (Simpson).

Premier Downs II.

One fragment, weight 4ozs.

Components: Kamacite, taenite, cohenite, graphite. (E.S.S. & H.B.)

Principal Reference: W.A. Geol. Survey Bulletin 59, p. 206 (Simpson & Bowley).

TABLE P.—*concluded.*

Name	Mt. Edith I.	Mt. Edith I.	Mt. Edith II. ⁽¹⁾	Mt. Edith II. ⁽²⁾
Class	Om.	Om.	Om.	Om.
Date of Discovery ..	1913.	1913.	1914.	1914.
Fe	[89·45]	89·500	88·48	89·66
Ni	9·45	9·450	9·06	9·18
Co	·75	·625	·65	·66
Cu	<i>Nil</i>	·013	..	..
Mn	<i>Nil</i>	<i>Nil</i>	..	..
Mg	<i>Nil</i>	<i>Nil</i>	..	..
P	·35	·316	·49	·50
S	<i>Nil</i> ⁽³⁾	·005	<i>Nil</i>	<i>Nil</i>
C Combined	}	·017	..	..
C Free		·005	..	..
Si	..	·005	..	..
O	<i>Nil</i>	<i>Nil</i>	[1·32]	<i>Nil</i>
Total	100·00	99·931	100·00	100·00
Sp. gr.	..	7·86	..	..
Analyst	E.S.S.	J. E. Whitfield.	E.S.S.	E.S.S.
Date	1913.	1914.	1914.	1914.

(¹) Actual analysis of small rusted fragments. (²) The same re-calculated after rejecting oxygen. (³) *Nil* in small fragment analysed, but probably not less than one per cent. in whole meteorite.

Mount Edith I.

One fragment, weight 355 lbs.

Components: Kamacite, taenite, troilite, schreibersite, cohenite. (E.S.S.)

Reference: American Journal of Science, XXXVII., p. 391. (Footnote.)

Mount Edith II.

One fragment, weight 364 lbs.

Components: Kamacite, taenite, schreibersite. (E.S.S.)

Part III.
NATURAL WATERS.

PART III.

ANALYSIS OF WESTERN AUSTRALIAN NATURAL WATERS.

The five tables under this section are arranged on a geographical basis as being more convenient for reference than any necessarily unsatisfactory attempt at an arrangement based upon composition.

For the most part it will be found that the waters are derived from either gold mines or artesian bores, though a fair number are derived from wells or surface springs; the "wells" from which State Battery water supplies are drawn are mostly abandoned gold mines. On the whole, whilst the total percentage of solid matter varies from 0.02 per cent. (14 grains per gallon) to 23.51 per cent. (16,457 grains per gallon), the composition of the solid matter does not vary greatly. It consists mainly of the "cyclic salts," *i.e.*, the salts common in sea water, and of these in almost every case common salt is in preponderating amount.

Within an area bounded roughly by Lats. 24° and 30° S. and Longs. 116° and 124° E. the underground waters contain, in addition to the usual cyclic salts, an appreciable amount of a soluble nitrate which in the following tables has been calculated as sodium nitrate. F. W. Clarke says:—⁽¹⁾

"Although waters containing small quantities of nitrates, borates or phosphates are not uncommon, waters in which these compounds are conspicuous are rare. Nitrates are usually regarded as evidence of pollution in waters, but they do not necessarily indicate pollution. In arid regions, where nitrification goes on rapidly, nitrates may occur in considerable amounts; some of the underground waters of Arizona contain as high as 160 parts per million of nitrogen in this form."

Within the area now mentioned sodium nitrate occurs to an extent ranging from a trace to 0.0362 per cent. (Marmont Mine, Meekatharra), the average of thirty-nine waters being 0.0111 per cent. NaNO_3 or 19 parts of nitric nitrogen per million. There can be little doubt that this accumulation of nitrates is the result of very active bacterial action in the soil, coupled with the low average rainfall, about 10 inches per annum. It is of interest to note that the most prominent plant growing in this region is "mulga," a variety of *Acacia*, a genus belonging to the order *Leguminosae*, the members of which are considered to promote indirectly the fixation of nitrogen in the soil.

(1) U. S. Geol. Survey Bulletin 491, p. 185. (1911).

The waters are almost entirely weakly alkaline in reaction, the bore waters of the coastal plain being more strongly alkaline than any others. Acid waters are apparently rare, even in the metaliferous areas where large bodies of sulphides are weathering. This is due to the fact that these sulphides are for the most part surrounded by greenstone schists of which some carbonate, either calcite, dolomite, ankerite, or mesitite is an invariable constituent (*vide* Tables F and G).

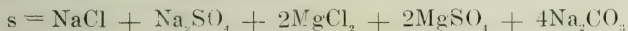
Numerically the constituents of water may be, or have been, expressed in grains per Imperial gallon, grammes per litre, parts per cent., per thousand, per hundred thousand, and per million. The first-named form of expression has not been adopted because it is not understood outside the British Empire, and because any decimal system of expression can readily be converted into it when required by a very simple multiplication. Thus, since there are 70,000 grains in a gallon, the proportion of any constituent given in parts per cent. is obtained in grains per gallon by multiplying by 700. In the tables calculated for salts the constituents are given in parts per cent., since this is the usual method of expressing the composition of all other substances and because confusion invariably occurs under other decimal systems of expression as to whether parts per 1,000, 10,000, 100,000, or 1,000,000 are in use.⁽¹⁾

During recent years the constituents in many published analyses of waters have been stated as far as possible in the ionic form. For purposes of comparison with such analyses this method of expression has been given here, as well as the more generally understood method of expression as salts. In the latter case the system of combination adopted has been such as to show the chief simple salts which would separate out on slow evaporation of the water at the earth's surface under atmospheric conditions.

The principal uses to which the waters here described are put are: human consumption, stock watering, irrigation, steam-raising, and gold extraction. Waters containing as much as 0.50 per cent. of total solids (mostly cyclic salts) have been used regularly for drinking on the goldfields, though such saline waters should be and are usually condensed for drinking whenever the solids exceed about 0.20 per cent. Stock are found to thrive on waters containing not more than 0.60 per cent. solids, and will tolerate even more when they have been reared on saline water. For stamp battery purposes waters of all qualities are used up to 25 per cent. solid matter, but for cyaniding a comparatively pure water must be used or one well softened with caustic soda. For steam-raising the quality demanded is much the same as for human consumption.

⁽¹⁾ See for example the table of analyses of mineral waters in Thorpe's Dictionary of Applied Chemistry, 1st Edition, pp. 952-959, where amongst other similar misstatements, saturated brine is said to contain 25.648 parts of sodium chloride per ten thousand.

preliminary softening being practiced with faintly brackish waters and condensing with still more saline supplies. For irrigation the following formula approximates to local practice: Let



All expressed in parts per cent., then the practical adaptability for irrigation is as follows:—

$s = 0$ to 0.05 . Excellent quality for irrigation on any type of soil with high or low rainfall.

$s = 0.05$ to 0.10 . Good for irrigation on loose soil or well drained heavy soil with fair rainfall.

$s = 0.10$ to 0.15 . Can be used for irrigation only on well drained loose soil in large quantities and with heavy seasonal rains.

$s = 0.15$ upwards. Valueless for irrigation.

According to the latest tables there are ninety-three deep bores in Western Australia yielding water, from only nineteen of which has water been analysed in the Survey Laboratory. It is to be hoped that as time goes on sufficient staff will be made available, not only to analyse the waters of all bores put down in the State, but to do so at periodic intervals so as to determine whether this important source of water supply is growing better or worse in quality with effluxion of time, and with increase in the number of bores which draw upon it.

TABLE Q.—WATERS—KIMBERLEY AND NORTH-WEST DIVISIONS.

G.S.L. No. ..	B2580.	A1573.	A1571.	B1825.	Qa.
Source	Hot Spring.	Public Well.	Hotel Well.	Battery Well.	Pelican Hill Bore.
Locality	Cone Bay.	Marble Bar.	Nullagine.	Sandy Creek.	Carnarvon.

SALTS—PARTS PER CENT.

CaCO ₃	·0016	·0213	·0171	·0100	·0187
MgCO ₃	..	·0250	·0305	·0234	·0034
FeCO ₃	..	·0001	·0002	·0002	..
Na ₂ CO ₃	..	·0067	..	·0304	..
CaSO ₄	·0017	..	..	..	·0400
MgSO ₄	·0029	..	·0633	..	·0314
Na ₂ SO ₄	..	·0108	·0708	·0534	·0268
K ₂ SO ₄	..	·0009	·0227	·0004	..
NaNO ₃	<i>Nil</i>	..	..	·0006	..
MgCl ₂	·0062	..	..	..	..
NaCl	·0398	·0485	·1700	·0824	·3372
KCl	·0019	..	..	..	..
Al ₂ O ₃ (Fe ₂ O ₃) ..	·0008	·0002	·0009	·0001	Trace
SiO ₂	·0026	·0055	·0025	·0035	·0019
Total Solids ..	0·0575	0·1190	0·3780	0·2044	0·4594
H ₂ S	<i>Nil</i>	Trace	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
Analyst	C.C.W.	E.S.S.	E.S.S.	E.S.S.	Government Analyst.
Date	1906.	1899.	1899.	1906.	1903.

TABLE Q.—concluded.

G.S.L. No. ..	B2580.	A1573.	A1571.	B1825.	Qa.
Locality ..	Cone Bay.	Marble Bar.	Nullagine.	Sandy Creek.	Carnarvon.

IONS—PARTS PER MILLION.

Cl	296	294	1,031	500	2,045
SO ₄	35	78	1,109	363	714
CO ₃	10	344	321	400	136
NO ₃	<i>Nil</i>	..	..	4	..
Na	157	255	898	631	1,414
K	10	4	102	2	..
Ca	11	85	68	40	193
Mg	22	72	216	67	73
Fe	..	1	1	1	..
Al ₂ O ₃ (Fe ₂ O ₃) ..	8	2	9	1	Trace
SiO ₂	26	55	25	35	19
Total Solids ..	575	1,190	3,780	2,044	4,594

B2580. Hot Spring, near Cone Bay, Kings Sound (E. 51).

A1573. Public Well, Marble Bar (F. 50).

Depth, 40 feet. Rock, slate.

A1571. Hotel Well, Nullagine (F. 51).

Rock, alluvium and slate

B1825. Battery Well, Sandy Creek (F. 51).

Rock, slate.

Qa. Pelican Hill Bore, Carnarvon (G. 49).

Depth, 3,011 feet. Rock at bottom, Carboniferous sandstone.

Original supply, 520,000 gals. per diem. References: A.R., 1902, p. 23; A.R. 1903, p. 34.

TABLE R.—WATERS—MURCHISON DIVISION.

G.S.L. No. ..	A4531.	B1274.	B2085.	D5372.	D6974.	D6793.
Source ..	Gold Mine.	Battery Well.	Com- modore North Mine	Kyarra Mine.	Marmont Mine.	Rocklee Mine.
Locality ..	Gaba- ninha.	Meeka- tharra.	Meeka- tharra.	Meeka- tharra.	Meeka- tharra.	Meeka- tharra.

SALTS—PARTS PER CENT.

CaCO ₃	·0090	·0271	·0084	·0282	·0335	·0221
MgCO ₃	·0077	..	·0126	..	·0078	·0117
FeCO ₃	..	..	·0002	..	..	..
CaSO ₄	..	·0177	..	·0026	..	..
MgSO ₄	·0075	·1243	·0204	·0380	·2825	·0441
Na ₂ SO ₄	..	..	..	..	..	·0041
K ₂ SO ₄	..	..	..	..	..	·0013
NaNO ₃	..	·0231	·0104	·0076	·0362	<i>Nil</i>
MgCl ₂	·0047	·1540	·0093	·0226	·2655	..
NaCl	·0218	·3296	·0422	·1199	·7022	·1182
KCl	..	·0036	·0016	·0097	·0192	..
NaI	..	..	<i>Nil</i>	..	..	..
NaBr	..	..	<i>Nil</i>	..	..	..
Al ₂ O ₃ (Fe ₂ O ₃) ..	·0003	·0004	·0011	·0006	·0005	·0006
B ₂ O ₃	..	..	Strong trace.	..	..	..
P ₂ O ₅	..	Trace	·0001	..	..	..
SiO ₂	·0058	·0046	·0034	·0050	·0039	·0028
Total Solids ..	0·0563	0·6844	0·1097	0·2342	1·3513	0·2049
Extra CO ₂	..	..	·0091	..	·0240	·0192
H ₂ S	..	..	<i>Nil</i>	..	<i>Nil</i>	<i>Nil</i>
Analyst	E.S.S.	E.S.S.	E.S.S.	H.B.	H.B.	H.B.
Date	1903.	1905.	1906.	1913.	1914.	1914.

TABLE R.—*continued.*

G.S.L. No. ..	A4501.	B1274.	B2085.	D5372.	D6794.	D6793.
Locality ..	Gaba-nintha.	Meeka-tharra.	Meeka-tharra.	Meeka-tharra.	Meeka-tharra.	Meeka-tharra.
Cl	167	3,163	333	941	6,328	717
SO ₄	60	1,117	163	321	2,254	387
CO ₃	109	163	141 ⁽¹⁾	169	257 ⁽²⁾	215
NO ₃	..	168	76	55	264	<i>Nil</i>
PO ₄	..	Trace	1	..	..	..
B ₄ O ₇	..	..	str. tr.	..	..	..
Na	86	1,360	194	493	2,860	478
K	..	19	8	51	101	6
Ca	36	160	34	121	134	89
Mg	49	644	101	135	1,271	123
Fe	..	..	1	..	..	..
Al ₂ O ₃ (Fe ₂ O ₃)..	3	4	11	6	5	6
SiO ₂	58	46	34	50	39	28
Total Solids ..	568	6,844	1,097	2,342	13,513	2,049
Extra CO ₂ ..	..	..	91 ⁽¹⁾	..	240 ⁽²⁾	192

⁽¹⁾ May be stated as : HCO₃, 252 ; CO₃, 17.

⁽²⁾ May be stated as : H, 2 ; HCO₃, 523 ; CO₃, 70.

A4501. From shaft of a gold mine, name not disclosed, Gabanintha (G. 50).

B1274. State Battery Well, Reserve 9142, Meekatharra (G. 50).

Rock, sheared tuff.

B2085. Commodore North Gold Mines, Meekatharra (G. 50).

Rock, sheared tuff with porphyry dyke.

D5372. Kyarra Gold Mine, Meekatharra (G. 50).

Rock, chloritic schist.

D6794. Marmont Gold Mine, Meekatharra (G. 50).

Depth, 320 feet. Rock, quartz porphyry near contact with serpentine and chlorite schists.

D6793. Rocklee Gold Mine, Meekatharra (G. 50).

From 170 feet in main shaft. Rock, soft greenstone schist.

Used for battery, stock watering and human consumption.

TABLE R.—*continued.*

G.S.L. No. . .	D6716.	D7052.	D7051.	D6924.	D6925.	D6715.
Source ..	Fenian Mine.	Commo-dore Mine.	Commo-dore Mine.	Globe Mine.	Ingliston Extended Mine.	Queen of the Hills Mine.
Locality ..	Meeka-tharra.	Meeka-tharra.	Meeka-tharra.	Meeka-tharra.	Meeka-tharra.	Meeka-tharra.

SALTS—PARTS PER CENT.

CaCO ₃ ..	·0150	·0091	·0073	·0232	·0084	·0175
MgCO ₃ ..	..	·0121	·0301	·0076	·0192	·0098
CaSO ₄ ..	·0568	..	..	..	..	..
MgSO ₄ ..	·1179	·0209	·0143	·1575	·0612	·0528
K ₂ SO ₄ ..	..	..	·0300	..	..	..
NaNO ₃ ..	<i>Nil</i>	·0204	·0111	·0188	·0214	·0157
MgCl ₂ ..	·0918	·0059	..	·0654	·0411	·0188
NaCl ..	·5851	·0453	·0645	·4176	·1172	·1216
KCl ..	·0074	·0013	·0053	·0053	·0006	·0022
Al ₂ O ₃ (Fe ₂ O ₃)..	·0002	·0010	·0005	·0003	·0004	·0002
SiO ₂ ..	·0016	·0041	·0033	·0038	·0020	·0034
Total Solids ..	0·8758	0·1201	0·1664	0·6995	0·2715	0·2420
Extra CO ₂ ..	·0078	·0107	·0183	·0166	·0127	·0163
H ₂ S ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
Analyst ..	E.S.S.	H.B.	H.B.	H.B.	H.B.	E.S.S.
Date ..	1914.	1915.	1915.	1915.	1915.	1914.

TABLE R.—*continued.*

G.S.L. No. ..	D6716.	D7052.	D7051.	D6924.	D6925.	D6715.
Locality ..	Meekatharra.	Meekatharra.	Meekatharra.	Meekatharra.	Meekatharra.	Meekatharra.
IONS—PARTS PER MILLION.						
Cl	4,268	325	416	3,045	1,020	888
SO ₄	1,342	167	279	1,257	488	421
CO ₃	90	141	258	193	187	175
NO ₃	<i>Nil</i>	149	81	137	156	115
Na	2,302	233	284	1,694	519	520
K	39	7	163	28	3	12
Ca	227	36	29	93	34	70
Mg	472	92	116	507	284	183
Al ₂ O ₃ (Fe ₂ O ₃)..	2	10	5	3	4	2
SiO ₂	16	41	33	38	20	34
Total Solids ..	8,758	1,201	1,664	6,995	2,715	2,420
Extra CO ₂ ..	78	107	183	166	127	163

D6716. Fenian Gold Mine, Meekatharra (G. 50).

From main shaft at depth of 830 feet. Water issuing from flat fault plane in chlorite schists seamed with calcite.

Density at 25deg. C., 1.0035.

D7052. Commodore Gold Mine, Meekatharra (G. 50).

300ft. level from west lode in serpentine schists.

Supply about 15,000 gals. a day.

D7051. Commodore Gold Mine, Meekatharra (G. 50).

400ft. level, from East lode at junction between serpentine schists and fuchsite-mesitite rock.

Supply about 4,000 gals. a day.

D6924. Globe Gold Mine, Meekatharra (G. 5)).

210ft. level close to main shaft. Water level is at 130 feet.

Rock, fuchsite-peridotite.

Supply about 6,000 gals. a day.

D6925. Ingliston Extended Gold Mine, Meekatharra (G. 50).

Depth, 425 feet. Rock, fuchsite-peridotite.

D6715. Queen of the Hills Gold Mine, Meekatharra (G. 50).

Drive at 450 feet. Rock, fine schists or slates.

Used in battery. Density at 25deg. C., 0.9988.

TABLE R.—*continued.*

G.S.L. No. ..	D7234.	D7233.	A4140.	A4261.	B889.	B1281.
Source ..	Wells 3 and 5.	Well 3.	Murchison Associated Mine.	Emperor Mine.	Great Fingall Mine.	Battery Well, Len- nonville.
Locality ..	Garden Gully.	Garden Gully.	Cue	Cue.	Cue.	Lennon- ville.

SALTS—PART PER CENT.

CaCO ₃ ..	·0182	·0186	·0200	·0250	·0193	·0304
MgCO ₃ ..	·0111	·0102	..	..	..	..
CaSO ₄ ..	..	..	·0685	·3054	·3256	·0184
MgSO ₄ ..	·0245	·0262	..	·3239	..	·1441
NaNO ₃ ..	·0056	·0069	Traces	Traces	·0217	·0055
CaCl ₂ ..	..	..	·0207	..	·0274	..
MgCl ₂ ..	·0031	·0023	·1007	·5895	·5464	·1086
NaCl ..	·0819	·0819	·2433	4·8255	1·4262	·5842
KCl ..	·0034	·0027	·0015	Traces	·0179	·0069
Al ₂ O ₃ ..	·0003	Trace	·0028	·0062	Trace	·0004
Fe ₂ O ₃ ..	Trace	·0002	Trace	Trace	Trace	Trace
P ₂ O ₅ ..	..	..	..	..	..	Trace
SiO ₂ ..	·0062	·0069	·0064	·0031	·0027	·0018
Total Solids ..	0·1543	0·1559	0·4639	6·0786	2·3872	0·9003
Extra CO ₂ ..	·0156	·0141	..	..	..	..
Analyst ..	H.B.	H.B.	J.H.B.	E.S.S.	J.H.B.	C.C.W.
Date ..	1915.	1915.	1903.	1903.	1905.	1905.

TABLE R.—*continued*.

G.S.L. No. ..	D7234.	D7233.	A4140.	A4261.	B889.	B1281.
Locality ..	Garden Gully.	Garden Gully.	Cue.	Cue.	Cue.	Lennonville.
Cl	536	527	2,365	33,660	12,979	4,386
SO ₄	196	209	483	4,740	2,297	1,280
CO ₃	188	185	120	150	116	182
NO ₃	41	50	Traces	Traces	158	40
Na	337	341	957	18,984	5,670	2,313
K	18	14	8	Traces	94	36
Ca	73	74	357	999	1,135	176
Mg	89	88	257	2,160	1,396	568
Al ₂ O ₃ (Fe ₂ O ₃) ..	3	2	28	62	Trace	4
SiO ₂	62	69	64	31	27	18
Total Solids ..	1,543	1,559	4,639	60,786	23,872	9,003
Extra CO ₂ ..	156	141	..	..	..	..

D7234. Mixed water from Mines Water Supply Wells 3 and 5, Garden Gully, 9 miles north of Meekatharra (G. 50).

Rock, weathered schists.

D7233. Mines Water Supply Well 3, Garden Gully, 9 miles north of Meekatharra (G. 50).

Rock, weathered schists.

A4140. Murchison Associated Gold Mine (Rubicon Lease), Day Dawn, Cue (G. 50).

Rock, epidiorite.

A4261. Emperor Gold Mine, Day Dawn, Cue (G. 50).

Rock, amphibolite.

B889. Great Fingall Gold Mine, Day Dawn, Cue (G. 50).

Rock, amphibolite.

B1281. State Battery Well, Lennonville (G. 50).

Rock, greenstone with jasper bars.

TABLE R.—continued.

G.S.L. No.	B1280.	B2538.	B2537.	B3211.	C3090.	C3089.	C3458.
Source ..	Battery Well.	Havalah Mine.	Mt. Ford Mine.	Wagoo Well.	Spring.	Durawah Spring.	Well.
Locality ..	Boogar-die.	Paynes-ville.	Paynes-ville.	Paynes-ville.	Mt. Erin.	Mt. Erin.	Willow Gully.

SALTS—PARTS PER CENT.

CaCO ₃ ..	·0079	·0136	·0132	·0062	·0040	·0017	·0041
MgCO ₃ ..	·0080	·0071	·0075	·0042	..	..	·0100
FeCO ₃ ..	..	..	..	·0002	Trace	Trace	<i>Nil</i>
Na ₂ CO ₃ ..	·0036	..	..	..	..	..	·0036
CaSO ₄ ..	..	..	..	..	·0095	·0026	..
MgSO ₄ ..	..	·0116	·0111	·0054	·0087	·0096	..
Na ₂ SO ₄ ..	·0149	..	..	·0092	..	..	·0088
K ₂ SO ₄ ..	·0009	..	..	·0020	..	..	·0004
NaNO ₃ ..	·0079	·0154	·0134	·0112	Trace	<i>Nil</i>	·0061
MgCl ₂ ..	..	·0129	·0125	..	·0301	·0090	..
NaCl ..	·0501	·0224	·0229	·0597	·1566	·0836	·0678
KCl ..	..	·0015	·0015	..	·0019	·0006	..
NaBr ..	..	..	..	·0001	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
NaI ..	..	..	..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
Al ₂ O ₃ (Fe ₂ O ₃)	·0012	·0006	·0004	·0005	·0019	·0011	·0002
B ₂ O ₃ ..	..	..	..	·0001	Trace	<i>Nil</i>	<i>Nil</i>
P ₂ O ₅ ..	..	..	..	<i>Nil</i>	Trace	Trace	Trace
SiO ₂ ..	·0060	·0040	·0032	·0041	·0064	·0034	·0063
Total Solids	0·1005	0·0891	0·0857	0·1029	0·2191	0·1116	0·1073
Extra CO ₂ ..	..	..	..	·0059	..	..	..
H ₂ S ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	Trace	<i>Nil</i>	<i>Nil</i>
Analyst ..	C.C.W.	C.C.W.	C.C.W.	E.S.S.	H.B.	H.B.	H.B.
Date ..	1905.	1906.	1906.	1907.	1909.	1909.	1909.

TABLE R.—concluded.

G.S.L. No.	B1280.	B2538.	B2537.	B2311.	C3090.	C3089.	C3458.
Locality ..	Boogardie.	Paynesville.	Paynesville.	Paynesville.	Mt. Erin.	Mt. Erin.	Willow Gully.
IONS—PARTS PER MILLION.							
Cl	304	239	239	362	1,183	577	411
Br	..	..	..	1	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
SO ₄ ..	106	93	89	117	136	95	62
CO ₃ ..	124	133	132	68	24	10	116
NO ₃ ..	58	112	98	82	Trace	<i>Nil</i>	45
PO ₄ ..	..	..	..	<i>Nil</i>	Trace	Trace	Trace
B ₄ O ₇ ..	..	..	..	1	Trace	<i>Nil</i>	<i>Nil</i>
Na	282	130	126	294	616	329	327
K	4	8	8	9	10	3	2
Ca	32	54	53	25	44	15	16
Mg	23	76	76	23	95	42	29
Fe	..	..	..	1	..	..	..
Al ₂ O ₃ (Fe ₂ O ₃)	12	6	4	5	19	11	2
SiO ₂ ..	60	40	32	41	64	34	63
Total Solids	1,005	891	857	1,029	2,191	1,116	1,073
Extra CO ₂ ..	..	..	..	59	..	..	..
H ₂ S ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	Trace	<i>Nil</i>	<i>Nil</i>

B1280. State Battery Well, Reserve 9769, Boogardie (G. 50).
Rock, greenstone with jasper bars.

B2538. Havalah Gold Mine, Paynesville (H. 50).

Rock, greenstone schist.

B2537. Mt. Ford Gold Mine, Paynesville (H. 50).

Rock, granite.

B3211. Wagoo Well, near Paynesville (H. 50).

Rock, granite.

C3090. Spring on Lot 42, Mt. Erin (H. 50).

Rock, Jurassic sediments with thin covering of Recent diatomite.

C3089. Durawah Spring, Reserve 89, 6 miles S.E. of Mt. Erin (H. 50).

Rock, Jurassic shales with thin covering of Recent diatomite.

C3458. Well at Homestead, Loc. 428, Willow Gully, Lower Bowes River, Northampton.

Rock, gneiss, with adjacent hills of Jurassic sandstone and Tertiary limestone.

TABLE S.—WATERS—CENTRAL DIVISION.

G.S.L. No. ..	B3097	B1401	B3098	B1275	B1276	Sa.
Source ..	Well.	Battery Well.	Well.	Battery Well.	Ballan-garry Mine.	Battery Well.
Locality ..	Maninga-Marley.	Black Range.	Rafferty's Patch.	Wiluna.	Darlot.	Duketon.

SALTS—PARTS PER CENT.

CaCO ₃	·0150	·0198	·0070	·0198	·0118	·0209
MgCO ₃	·0073	·0080	·0190	·0124	..	·0056
CaSO ₄	..	..	..	..	·0031	·0004
MgSO ₄	·0167	·0574	..	·0508	·0042	·0139
Na ₂ SO ₄	·0055	·0495	·0144	..	..	·0021
K ₂ SO ₄	..	·0024	..	..	..	..
NaNO ₃	·0164	·0222	·0135	·0181	·0135	..
MgCl ₂	..	..	..	·0078	·0090	..
NaCl	·0660	·3415	·0511	·0650	·0201	·0384
KCl	..	..	..	·0012	·0059	..
Al ₂ O ₃ (Fe ₂ O ₃) ..	·0005	·0010	·0002	·0001	·0008	·0001
SiO ₂	·0060	·0055	·0045	·0048	·0046	·0005
Total Solids ..	0·1334	0·5073	0·1097	0·1800	0·0730	0·0819
Analyst	C.C.W.	J.H.B.	C.C.W.	E.S.S.	C.C.W.	Govt. Analyst.
Date	1907	1905	1907	1905	1905	1905

TABLE S.—*continued.*

G.S.L. No. ..	B3097	B1401.	B3098.	B1275.	B1276.	Sa.
Locality ..	Maninga-Marley.	Black Range.	Rafferty's Patch.	Wiluna.	Darlot.	Duketon,
Cl	400	2072	310	458	217	233
SO ₄	170	806	97	405	56	128
CO ₃	142	176	177	207	71	165
NO ₃	120	162	99	132	98	..
Na	322	1563	284	305	116	158
K	..	11	..	6	31	..
Ca	60	79	28	79	56	85
Mg	55	139	55	159	31	44
Al ₂ O ₃ (Fe ₂ O ₃) ..	5	10	2	1	8	1
SiO ₂	60	55	45	48	46	5
Total Solids ..	1334	5073	1097	1800	730	819

B3097. Town Well, Maninga-Marley (H. 50).

Rock, granite.

B1401. State Battery Well, Reserve 9768, midway between Sandstone and Nungarra, Black Range (H. 50).

Rock, greenstone.

B3098. Government Well, Rafferty's Patch, Black Range (H. 50).

Rock, greenstone.

B1275. State Battery Well, Reserve 9909, Wiluna (G. 51).

Rock, greenstone.

B1276. Ballangarry Gold Mine, Darlot (G. 51).

Rock, greenstone.

Sa. State Battery Well, Duketon (G. 51).

TABLE S.—*continued.*

G.S.L. No. ..	B441.	B2065.	B675.	B1254.	B315.	B1271.
Source ..	Battery Well.	Battery Well.	Harrison Mine.	Battery Well.	?	Battery Well.
Locality ..	Burtville.	Burtville.	Pig Well.	Leonora.	Mt. Ida.	Mt. Ida.

SALTS—PARTS PER CENT.

CaCO ₃	·0221	·0219	·0509	·0494	·0213	·0130
MgCO ₃	..	·0040	..	·0124	..	·0161
FeCO ₃	·0016	Trace	Trace	Trace	Trace	·0001
CaSO ₄	·0041	..	·0106	..	·0840	..
MgSO ₄	·0361	·0271	·1642	·1711	·0742	·0081
Na ₂ SO ₄	·0016	·0080	..	·0440	..	·0438
K ₂ SO ₄	·0103	·0050	..	·0048	..	·0002
NaNO ₃	Traces	·0035	·0004	·0181	..	·0055
MgCl ₂	..	..	·0101	..	·0203	..
NaCl	·1431	·1101	·5144	·4299	·7148	·1933
KCl	..	..	·0241	..	..	..
NaBr	..	..	..	..	..	·0001
NaI	..	..	..	..	..	<i>Nil</i>
Al ₂ O ₃ (Fe ₂ O ₃) ..	Trace	·0003	Trace	·0014	Trace	·0007
B ₂ O ₃	..	..	..	..	..	Trace
P ₂ O ₅	..	..	..	..	..	<i>Nil</i>
SiO ₂	·0010	·0020	·0016	·0055	·0020	·0029
Total Solids ..	0·2199	0·1819	0·7763	0·7366	0·9166	0·2838
Analyst ..	J.H.B.	E.S.S.	J.H.B.	J.H.B.	J.H.B.	E.S.S.
Date	1904	1905	1905	1905	1904	1905

TABLE S.—*continued.*

G.S.L. No. ..	B441.	B2065.	B675.	B1254.	B315.	B1271.
Locality ..	Burtville.	Burtville.	Pig Well.	Leonora.	Mt. Ida.	Mt. Ida.

IONS—PARTS PER MILLION.

Cl	868	668	3310	2608	4487	1173
Br	..	..	..	..	..	1
SO ₄	385	298	1385	1689	1185	362
CO ₃	141	159	305	384	128	193
NO ₃	Trace	26	3	132	..	40
B ₄ O ₇	..	..	..	..	..	Trace
Na	568	468	2025	1882	2812	917
K	46	22	126	22	..	1
Ca	100	88	235	198	332	52
Mg	73	67	358	382	202	62
Fe	8	Trace	Trace	Trace	Trace	1
Al ₂ O ₃ (Fe ₂ O ₃) ..	Trace	3	Trace	14	Trace	7
SiO ₂	10	20	16	55	20	29
Total Solids ..	2199	1819	7763	7366	9166	2838

B441 and B2065. State Battery Well, Reserve 8914, Burtville (H. 51).

Rock, greenstone, with quartz-haematite bars.

B675. Harrison Gold Mine, Pig Well (H. 51).

B1254. State Battery Well, Reserve 7121, Leonora (H. 51).

Rock, greenstone schists.

B315. Source unknown, Mt. Ida (H. 51).

B1271. State Battery Well, Mt. Ida (H. 51).

Rock, greenstone schist.

TABLE S.—*continued.*

G.S.L. No. ..	B1272.	B1278.	B1279.	D7685.	D7683.	D7548.
Source ..	Ida Mine.	Battery Well.	Battery Well.	Battery Well.	Orion Mine.	Altona Mine.
Locality ..	Mt. Ida.	Yunda-mindera.	Niagara.	Niagara.	Niagara.	Kookynie.

SALTS—PARTS PER CENT.

CaCO ₃ ..	·0189	·0144	·0286	·0307	·0259	·0022
MgCO ₃ ..	..	..	..	..	..	·0107
Na ₂ CO ₃ ..	..	..	..	..	..	·0307
CaSO ₄ ..	·1134	·0087	·0056	·0200	·1624	..
MgSO ₄ ..	·0612	·0156	·0708	·0628	·0393	..
Na ₂ SO ₄ ..	..	..	..	..	..	·0290
K ₂ SO ₄ ..	..	..	..	..	..	·0067
NaNO ₃ ..	·0011	·0085	·0156	·0122	·0012	·0019
MgCl ₂ ..	·0431	·0188	·0161	·0462	·3438	..
NaCl ..	·7341	·0571	·2876	·3118	·3961	·1167
KCl ..	·0004	·0028	·0028	·0023	·0084	..
Al ₂ O ₃ (Fe ₂ O ₃) ..	·0003	·0004	·0009	·0006	·0011	·0003
P ₂ O ₅ ..	<i>Nil</i>	<i>Nil</i>	..	..	..	..
SiO ₂ ..	·0016	·0040	·0046	·0047	·0045	·0053
Total Solids ..	0·9741	0·1303	0·4326	0·4913	0·9827	0·2035
Extra CO ₂ ..	..	..	..	·0123	·0062	·0169
Analyst ..	E.S.S.	C.C.W.	E.S.S.	H.B.	H.B.	H.B.
Date ..	1905	1905	1905	1915	1915	1915

TABLE S.—*continued.*

G.S.L. No. ..	B1272.	B1278.	B1279.	D7685.	D7683.	D7548.
Locality ..	Mt. Ida.	Yunda- mindera.	Niagara.	Niagara.	Niagara.	Kookynie.

IONS—PARTS PER MILLION.

Cl	4776	499	1878	2246	5003	708
SO ₄	1288	185	605	642	1460	223
CO ₃	113	86	171	182	155	263
NO ₃	8	62	114	89	9	14
Na	2891	248	1173	1260	1561	691
K	2	15	15	12	44	30
Ca	410	84	131	182	582	9
Mg	234	80	184	245	967	31
Al ₂ O ₃ (Fe ₂ O ₃) ..	3	4	9	6	11	3
SiO ₂	16	40	46	47	45	53
Total Solids ..	9741	1303	4326	4913	9827	2035
Extra CO ₂ ..	..	..	..	123	62	169

B1272. Ida Gold Mine, Mt. Ida (H. 51).

Rock, greenstone schist.

B1278. State Battery Well, Yundamindera (H. 51).

Rock, granite.

B1279 and D7685. State Battery Well, Niagara (H. 51).

Rock, granite or granodiorite.

D7683. Orion Gold Mine, Niagara (H. 51).

Depth, 275 feet. Rock, greenstone.

D7548. Altona Gold Mine, Kookynie (H. 51).

Depth, 150 feet. Rock, granodiorite.

TABLE S.—*continued.*

G.S.L. No.	Sb.	B1513.	B1125.	A1181.	A2253.	B2064.	B2066.
Source ..	Battery Well.	Well.	Anglo-Saxon Mine.	Menzies Consolidated Mine.	Battery Well.	Battery Well.	Battery Well.
Locality ..	Yarrie.	Pingin.	Pingin.	Menzies.	Mulline.	Mulline.	Mul-warrie.

SALTS—PARTS PER CENT.

CaCO ₃ ..	·0208	·0382	·0211	·0134	·0232	·0241	·0516
MgCO ₃ ..	·0199	..	·0174	..	..	..	..
FeCO ₃ ..	Trace	Trace	Trace	·0002	Trace	Trace	Trace
CaSO ₄ ..	·0218	·0220	..	·1607	·0095	·0128	·0919
MgSO ₄ ..	·0267	·0652	·0702	·4787	·1728	·2029	·2952
Na ₂ SO ₄ ..	..	..	·0403	..	..	..	..
NaNO ₃ ..	·0050	·0157	·0063	..	..	<i>Nil</i>	<i>Nil</i>
MgCl ₂ ..	·0131	·0286	..	·2696	·0478	·0691	·2570
NaCl ..	·2313	·2989	·5728	2·6449	·8985	1·0153	1·6286
KCl ..	..	·0036	·0118	·0076	..	·0286	·0419
NaBr ..	..	..	..	Trace	..	..	..
Al ₂ O ₃ (Fe ₂ O ₃)	·0001	·0005	·0004	·0029	·0020	·0012	·0016
SiO ₂ ..	·0069	·0032	·0024	·0023	·0077	·0083	·0060
Total Solids	0·3456	0·4759	0·7427	3·5803	1·1615	1·3623	2·3738
Analyst ..	Govt. Analyst	J.H.B.	E.S.S.	E.S.S.	E.S.S.	J.H.B.	J.H.B.
Date ..	1905.	1905.	1905.	1899.	1900.	1905.	1905.

TABLE S.—*continued.*

G.S.L. No.	Sb.	B1513.	B1125.	A1181.	A2253.	B2064.	B2066.
Locality ..	Yarrie.	Pingin.	Pingin.	Menzies.	Mulline.	Mulline.	Mul-warrie.

IONS—PARTS PER MILLION.

Cl	1501	2043	3531	18088	5806	6810	11992
Br	..	..	..	Trace	..	..	..
SO ₄ ..	367	675	833	4954	1446	1709	3004
CO ₃ ..	267	229	251	81	139	145	309
NO ₃ ..	36	115	46	..	..	<i>Nil</i>	<i>Nil</i>
Na	924	1218	2400	10405	3535	3994	6407
K	..	19	62	39	..	150	220
Ca	147	218	84	527	121	134	478
Mg	144	205	192	1656	471	586	1252
Fe	Trace	Trace	Trace	1	Trace	Trace	Trace
Al ₂ O ₃ (Fe ₂ O ₃)	1	5	4	29	20	12	16
SiO ₂ ..	69	32	24	23	77	83	60
Total Solids	3456	4759	7427	35803	11615	13623	23738

Sb. State Battery Well, Yarrie (H. 51).

B1513. Town Well, Pingin (H. 51).

B1125. Anglo-Saxon Gold Mine, Pingin (H. 51).

A1181. Menzies Consolidated Gold Mine, Menzies (H. 51).

Rock, greenstone.

A2253 and B2064. State Battery Well, Reserve 7250, Mulline (H. 51).

Depth, 130 feet. Supply, 13,000 gals. per diem. Rock, amphibolite.

B2066. State Battery Well, Reserve 8045, Mulwarrie (H. 51).

Depth, 160 feet. Supply, 4,000 gals. per diem. Rock, amphibolite.

TABLE S.—*continued.*

G.S.L. No.	A1336.	A1339.	A1278.	A1276.	A2371.	A1171.	A1173.
Source ..	S. Gipps- land Mine.	Well.	Golden Lead Mine.	Hit or Miss Sth. Mine.	Well.	Well.	L. V. & B. June. Mine.
Locality ..	Vosper- ton.	Lindsays.	Mul- garrie.	Mul- garrie.	Bingie Bintie.	Mt. Hunt.	Kal- goorlie.

SALTS—PARTS PER CENT.

CaCO ₃ ..	·0242	·0142	·0068	·0503	·0316	·0323	·0395
MgCO ₃ ..	..	·0320	..	..	..	·0114	..
FeCO ₃ ..	·0005	Trace	·0012	Trace	Trace	Trace	Trace
CaSO ₄ ..	·1598	..	·1105	·0979	·0034	..	·1878
MgSO ₄ ..	·2512	·0216	·3116	·4397	·0403	·0406	·3908
Na ₂ SO ₄ ..	..	·0887	..	..	..	..	..
K ₂ SO ₄ ..	..	Trace	..	..	..	..	..
NaNO ₃ ..	Trace	..	..	Trace	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
MgCl ₂ ..	·3027	..	·2066	·3234	·0340	·0399	·5229
NaCl ..	3·0018	·4398	3·2303	2·7174	·2536	·0885	3·2142
KCl ..	·0547	..	·0349	·0700	·0131	Trace	·0700
NaBr ..	Trace	..	Str. tr.	·0031	..	..	..
NaI ..	<i>Nil</i>	Trace	<i>Nil</i>	Trace	..	..	..
Al ₂ O ₃ (Fe ₂ O ₃)	·0079	Trace	·0031	·0004	·0003	Trace	·0047
SiO ₂ ..	·0037	·0003	·0032	·0014	·0050	Trace	·0009
Total Solids	3·8065	0·5966	3·9082	3·7036	0·3813	0·2127	4·4308
Analyst ..	E.S.S.	E.S.S.	E.S.S.	E.S.S.	H.B.	E.S.S.	E.S.S.
Date ..	1899.	1899.	1899.	1899.	1912.	1899.	1899.

TABLE S.—*continued.*

G.S.L. No.	A1336.	A1339.	A1278.	A1278.	D2371.	A1171.	A1173.
Locality ..	Vosperton.	Lindsays.	Mulgarrie.	Mulgarrie.	Bingie Bintie.	Mt. Hunt.	Kalgoorlie.
Cl ..	20723	2668	21299	19225	1853	834	23724
Br ..	Trace	..	Trace	24	..	..	..
I ..	Nil	Trace	..	Trace	..	..	..
SO ₄ ..	3133	772	3267	4200	346	324	4444
CO ₃ ..	148	313	47	302	189	275	238
NO ₃ ..	Trace	..	..	Trace	..	..	..
Na ..	11809	2017	12708	10697	998	348	12645
K ..	287	Trace	183	367	69	Trace	367
Ca ..	567	57	352	489	137	129	710
Mg ..	1280	136	1157	1714	168	217	2124
Fe ..	2	Trace	6	Trace	Trace	Trace	Trace
Al ₂ O ₃ (Fe ₂ O ₃)	79	Trace	31	4	3	Trace	47
SiO ₂ ..	37	3	32	14	50	Trace	9
Total Solids	38065	5966	39082	37036	3813	2127	44308

A1336. South Gippsland No. 3 Gold Mine, Vosperton (Hayes' New Find) (H. 51).

Total depth, 240 feet; water level, 180 feet. Supply, 11,000 gals. Rock, Serpentine schist.

A1339. Well on Water Reserve, Lindsays (H. 51).

Depth, 180 feet. Supply, 300 gals. Rock, greenstone.

A1278. Golden Lead Gold Mine, Mulgarrie (H. 51).

Total depth, 125 feet; water level, 85 feet. Rock, greenstone.

A1276. Hit or Miss South Gold Mine, Mulgarrie (H. 51).

Total depth, 155 feet; water level, 83 feet. Supply, 35,000 gals. Rock, greenstone, with felsite dyke.

D2371. Well, Bingie Bintie, near Kanowna (H. 51).

A1171. Well on W.R. 154, Mt. Hunt, Kalgoorlie (H. 51).

Depth, 130 feet. Supply, 800 gals. Rock, amphibolite.

A1173. Main shaft, Lake View and Boulder Junction Gold Mine, G.M.L. 921E, Kalgoorlie (H. 51).

Supply, 20,000 gals. Rock, propylite.

TABLE S.—*concluded.*

G.S.L. No.	A1172.	Sc.	A1335.	A1452.	D6578.	B35.	A1196.
Source ..	Well.	?	Great Hanover Mine.	Rose Hill Mine.	Butcher Bird Mine.	Dam.	Tarcoola N. Mine.
Locality ..	Hannan's Lake.	Randells.	Cool-gardie.	Cool-gardie.	Marda.	Southern Cross.	Southern Cross.

SALTS—PARTS PER CENT.

CaCO ₃ ..	·0052	..	·0638	·0627	·0255	·010	·0093
MgCO ₃ ..	..	..	..	..	·0282	·002	·0307
FeCO ₃ ..	Trace	..	·0005	·0005	Trace	Trace	·0003
MnCO ₃ ..	..	..	..	..	Trace	..	..
Na ₂ CO ₃ ..	..	..	..	..	..	..	·0473
CaSO ₄ ..	·3984	·5887	·0316	·0184	..	..	..
MgSO ₄ ..	·4921	·1794	·4688	·4192	·0141	3·461	..
K ₂ SO ₄ ..	..	..	..	..	..	..	·1025
NaNO ₃ ..	..	..	..	..	<i>Nil</i>	..	·0030
MgCl ₂ ..	1·9260	·4976	·1258	·0662	·0133	6·055	..
NaCl ..	12·8371	7·9994	2·0196	1·7659	·6589	17·264	·3618
KCl ..	..	..	·0197	·0047	·0062	..	·0084
NaBr ..	..	..	<i>Nil</i>	Trace	..	..	..
NaI ..	..	..	Trace	<i>Nil</i>	..	..	..
Al ₂ O ₃ (Fe ₂ O ₃)	·0038	·0253	·0083	·0039	·0021	·003	·0002
SiO ₂ ..	·0047	·0183	·0033	·0040	·0018	·002	·0041
Total Solids	15·6673	9·3087	2·7414	2·3455	0·7501	26·797	0·5676
Analyst ..	E.S.S.	Govt. Analyst	E.S.S.	E.S.S.	H.B.	C.C.W.	E.S.S.
Date ..	1899.	1905.	1899.	1899.	1914.	1904.	1899.

TABLE S.—*concluded.*

G.S.L. No.	A1172.	Sc.	A1335.	A1452.	D6578.	B35.	A1196.
Locality ..	Hannan's Lake.	Randells.	Coolgardie.	Coolgardie.	Marda.	Southern Cross.	Southern Cross.

IONS—PARTS PER MILLION.

Cl	92211	52229	13282	11225	4125	152828	2235
Br	..	..	..	Trace	..	..	..
I	..	..	Trace	..	..	..	..
SO ₄ ..	6768	5586	3964	3504	113	27619	565
CO ₃ ..	41	..	386	379	354	74	544
NO ₃ ..	..	..	..	..	..	..	22
Na	50501	31470	7945	6947	2592	67917	1636
K	..	..	103	25	33	..	504
Ca	1154	1733	348	276	102	40	37
Mg	5913	1633	1268	1018	143	19442	89
Mn	..	..	..	..	Trace	..	..
Fe	Trace	..	2	2	Trace	Trace	1
Al ₂ O ₃ (Fe ₂ O ₃)	38	253	83	39	21	30	2
SiO ₂ ..	47	183	33	40	18	20	41
Total Solids	156673	93087	27414	23455	7501	267970	5676

A1172. Well on west side of Hannans Lake, Kalgoorlie (H. 51).

Rock, serpentine.

Sc. Unknown source (probably a gold mine), Randells (H. 51).

A1335. Main shaft, Great Hanover Gold Mine, Coolgardie (H. 51).

Total depth, 250 feet; water level, 140 feet. Supply, 100,000 gals. Rock, amphibolite with porphyry dyke.

A1452. Main shaft, Rose Hill Gold Mine, Coolgardie (H. 51). Total depth, 183 feet. Supply, 15,000 gals. Rock, amphibolite.

D6578. Butcher Bird Gold Mine, Marda (H. 50).

B35. Surface water collected in Dam, Southern Cross (H. 50).

A1196. Tareoola North Gold Mine, Southern Cross (H. 50).

TABLE T.—WATERS—SOUTH-WEST DIVISION.

G.S.L. No. . .	Ta.	Tb.	C1534.	C1519.	C1520.	C2706.
Source ..	Bore.	Yardarino Bore.	Yardarino Bore.	Irwin Spring.	Mondara Spring.	Moriary Spring.
Locality ..	Dongara.	Irwin.	Irwin.	Irwin.	Irwin.	Strawberry.

SALTS—PARTS PER CENT.

CaCO ₃ ..	·0291	·0069	·0052	Trace	·0014	·0003
MgCO ₃ ..	·1017	·0050	..	·0021	·0017	·0015
FeCO ₃ ..	Trace	Trace	Trace	..	..	·0002
CaSO ₄ ..	·1765	·0094	·0170	..	..	..
MgSO ₄ ..	·0024	·0096	·0063	·0029	·0041	·0031
K ₂ SO ₄ ..	..	·0077	..	..	..	..
NaNO ₃ ..	..	..	Nil	Nil	Nil	Nil
MgCl ₂ ..	·2244	·0077	·0317	..	·0027	·0007
NaCl ..	1·6498	·0969	·1789	·0365	·0497	·0402
KCl ..	..	..	..	·0011	..	·0012
NaBr ..	..	..	Nil	Nil	Nil	Nil
NaI ..	..	..	Nil	Nil	Nil	Nil
Al ₂ O ₃ (Fe ₂ O ₃) ..	·0021	·0006	·0007	Nil	·0004	·0001
B ₂ O ₃ ..	..	..	Nil	Nil	Nil	Trace
P ₂ O ₅ ..	..	..	Trace	Nil	Nil	Trace
SiO ₂ ..	..	·0009	·0014	·0026	·0032	·0039
Organic matter	Nil	Nil	Nil	Nil	Much	Trace
Total Solids ..	2·1860	·1447	·2412	·0452	·0632	·0512
H ₂ S ..	Nil	Nil	Nil	Nil	Nil	Nil
Analyst ..	Govt. Analyst	Govt. Analyst	C.C.W.	E.S.S.	C.C.W.	J.H.B.
Date ..	1899	1901	1908	1908	1908	1909

TABLE T.—*continued.*

G.S.L. No. ..	Ta.	Tb.	C1534.	C1519.	C1520.	C2706.
Locality ..	Dongara.	Irwin.	Irwin.	Irwin.	Irwin.	Strawberry.
Cl	11679	645	1321	226	321	255
SO ₄	1264	185	170	23	33	25
CO ₃	898	77	31	15	20	14
PO ₄	..	..	Trace	<i>Nil</i>	<i>Nil</i>	Trace
B ₄ O ₇	..	..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	Trace
Na	6490	381	704	144	196	158
K	..	35	..	6	..	6
Ca	637	56	71	Trace	6	1
Mg	871	53	94	12	20	12
Fe	Trace	Trace	Trace	..	..	1
Al ₂ O ₃ (Fe ₂ O ₃) ..	21	6	7	<i>Nil</i>	4	1
SiO ₂	..	9	14	26	32	39
Organic ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	Much	Trace
Total Solids ..	21860	1447	2412	452	632	512

Ta. Artesian Bore, Dongara (H. 50).

Total depth, 2,111 feet. Supply, 200,000 gals. per diem. Temperature, 104deg. F.

Rock, Mesozoic sandstones and shales.

Tb and C1534. Artesian Bore, Yardarino, Irwin (H. 50).

Total depth, 1,607 feet. Temperature, 86deg.

Rock, Mesozoic sandstones and shales. Used for watering stock.

C1519. Irwin Spring, Loc. 803, Irwin (H. 50).

Depth, 2 feet. Rock, Jurassic sandstone. Used for railway purposes.

C1520. Mondara Spring, Reserve 923, Irwin (H. 50).

Depth, 2 feet. Rock, Jurassic sandstone.

C2706. Moriary Spring, Loc. 257, 6 miles S.E. of Strawberry (H. 50).

Depth, 5 feet. Rock, Jurassic sandstone with thin covering of Recent diatomite.

TABLE T.—*continued.*

G.S.L. No. ..	C204.	C2705.	C488.	C489.	C203.	C1637.
Source ..	Well.	Mingenew Spring.	Eyragully Spring.	Ebano Spring.	Yungarloo Well.	Warraga Spring.
Locality ..	Lockier.	Mingenew.	Mingenew.	East Mingenew.	East Mingenew.	Upper Irwin.

SALTS—PARTS PER CENT.

H ₂ SO ₄ ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	·0058
CaCO ₃ ..	·0039	·0002	·0005	·0020	·0023	<i>Nil</i>
MgCO ₃ ..	..	·0017	·0011	·0011	·0029	<i>Nil</i>
FeCO ₃ ..	..	Trace	Trace	Trace	..	<i>Nil</i>
CaSO ₄ ..	..	..	..	..	..	·0225
MgSO ₄ ..	·0083	·0056	·0029	·0042	·0036	·0306
FeSO ₄ ..	..	..	..	..	..	·0003
Al ₂ (SO ₄) ₃ ..	..	..	..	..	..	·0327
Na ₂ SO ₄ ..	..	..	..	..	·0019	..
K ₂ SO ₄ ..	..	·0004	..	..	·0013	..
NaNO ₃ ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	·0013	·0101	<i>Nil</i>
MgCl ₂ ..	·0192	..	·0027	·0043	..	·0598
NaCl ..	·1178	·0473	·0373	·0418	·0543	·4335
KCl ..	·0038	·0015	·0011	·0011	..	·0068
NaBr ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	·0001
NaI ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
Al ₂ O ₃ ..	} ·0004	·0001	·0004	·0003	{ ·0005	..
Fe ₂ O ₃ ..						..
B ₂ O ₃ ..	Trace	Trace	str. tr.	<i>Nil</i>	Trace	..
P ₂ O ₅ ..	<i>Nil</i>	Trace	<i>Nil</i>	<i>Nil</i>	·0001	<i>Nil</i>
SiO ₂ ..	·0046	·0042	·0045	·0021	·0124	·0016
Organic matter	..	..	str. tr.	..	str. tr.	..
Total Solids	0·1580	0·0610	0·0505	0·0582	0·0911	0·5937
H ₂ S ..	Trace	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
Analyst ..	C.C.W.	J.H.B.	C.C.W.	C.C.W.	E.S.S.	H.B.
Date ..	1908	1909	1908	1908	1908	1908

TABLE T.—*continued.*

G.S.L. No. ..	C204.	C2705.	C488.	C489.	C203.	C1637.
Locality ..	Lockier.	Mingenew.	Mingenew.	East Mingenew.	East Mingenew.	Upper Irwin.
IONS—PARTS PER MILLION.						
H	..	..	..	..	..	1 ¹
Cl	866	294	251	293	330	3108
Br	..	..	..	..	..	1
SO ₄	66	47	23	34	49	737
CO ₃	23	13	11	20	36	<i>Nil</i>
NO ₃	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	9	74	<i>Nil</i>
PO ₄	<i>Nil</i>	Trace	<i>Nil</i>	<i>Nil</i>	1	<i>Nil</i>
B ₄ O ₇	Trace	Trace	Trace	<i>Nil</i>	Trace	..
Na	473	186	147	168	246	1704
K	20	10	6	6	6	36
Ca	16	1	2	8	9	66
Mg	66	16	16	22	14	215
Fe	..	Trace	Trace	Trace	..	1
Al	..	..	..	..	..	52
Al ₂ O ₃ (Fe ₂ O ₃) ..	4	1	4	3 {	Al ₂ O ₃ 5 } Fe ₂ O ₃ 17 }	..
SiO ₂	46	42	45	21	124	16
Organic ..	..	..	Trace	..	Trace	..
Total, solids	1580	610	505	582	911	5937

¹ More exactly, 1·18.**C204.** Well in Loc. 1825, Lockier (H. 50).

Depth, 107 feet. Rock, Jurassic (?) sandstone.

C2705. Mingenew Spring, Reserve 957, Mingenew (H. 50).

Depth, 6 feet. Rock, Carboniferous sandstone with covering of Recent diatomite.

Reference: B. 38, p. 68.

C488. Eyragully Spring, Loc. 378, Mingenew (H. 50).

Depth, 3 feet. Rock, Carboniferous sandstone with covering of Recent diatomite. Used for railway purposes.

Reference: B. 38, p. 68

C489. Ebano Spring, Loc. 716, 14 miles east of Mingenew (H. 50).

Depth of well, 15 feet. Rock, Carboniferous argillaceous sandstone.

Reference: B. 38, p. 70.

C203. Yungarloo Well, Loc. 2016, 16 miles east of Mingenew (H. 50).

Depth (?). Rock, gneiss.

Reference: B. 38, p. 70.

C1637. Warraga Spring, bed of Irwin River, close to S.W. corner of Reserve 2297, north-east of Mingenew (H. 50).

Rock, Carboniferous coal measures.

Reference: B. 38, p. 70.

TABLE T.—*continued.*

G.S.L. No. ..	B3751.	B3752.	B1839.	B3627.	Tc.	D4264.
Source ..	Spring.	Well.	Well.	Well.	Reservoir.	Bore.
Locality ..	Arrow-smith River.	Arrow-smith River.	Yandan-nooka.	Arrino.	Mundaring.	Gosnells.

SALTS—PARTS PER CENT.

CaCO ₃ ..	<i>Nil</i>	·0014	·0011	·0009	·0004	·0216
MgCO ₃ ..	·0010	·0010	·0013	..	·0025	·0004
FeCO ₃ ..	<i>Nil</i>	Trace	·0002	Trace	..	Trace
CaSO ₄ ..	..	..	..	·0010	·0027	..
MgSO ₄ ..	·0077	·0047	..	·0009	·0010	·0310
K ₂ SO ₄ ..	..	..	·0086	..	..	..
NaNO ₃ ..	<i>Nil</i>	<i>Nil</i>	·0011	·0069	..	<i>Nil</i>
MgCl ₂ ..	·0070	·0066	·0078	·0055	·0036	·0062
NaCl ..	·0673	·0487	·1293	·0028	·0302	·3556
KCl ..	·0030	·0013	·0015	·0011	..	·0100
NaBr ..	<i>Nil</i>	<i>Nil</i>	..	<i>Nil</i>	..	..
NaI ..	<i>Nil</i>	<i>Nil</i>	..	<i>Nil</i>	..	..
Al ₂ O ₃ (Fe ₂ O ₃) ..	<i>Nil</i>	<i>Nil</i>	·0001	·0002	Trace	·0016
B ₂ O ₃ ..	Very str. tr.	Str. tr.	..	Min. tr.	..	..
P ₂ O ₅ ..	<i>Nil</i>	Trace	..	<i>Nil</i>	..	..
SiO ₂ ..	·0042	·0045	·0097	0021	·0009	·0015
Organic matter	<i>Nil</i>	<i>Nil</i>	Str. tr.	<i>Nil</i>	..	<i>Nil</i>
Total Solids ..	0·0902	0·0682	0·1607	0·0214	0·0413	0·4279
Extra CO ₂ ..	..	·0057	..	..	..	..
Analyst ..	E.S.S.	E.S.S.	E.S.S.	E.S.S.	Govt. Analyst.	E.S.S.
Date ..	1908.	1908.	1906.	1908.	1910.	1913.

TABLE T.—*continued.*

G.S.L. No. ..	B3751.	B3752.	B1839.	B3627.	Tc.	D4264.
Locality ..	Arrowsmith River.	Arrowsmith River.	Yandanooka.	Arrino.	Mundaring.	Gosnells.

IONS—PARTS PER MILLION.

Cl	474	360	849	63	210	2251
SO ₄	61	38	47	14	27	247
CO ₃	7	15	18	5	20	133
NO ₃	<i>Nil</i>	<i>Nil</i>	8	50	..	<i>Nil</i>
PO ₄	<i>Nil</i>	Trace	..	<i>Nil</i>	..	..
B ₄ O ₇	Trace	Trace	..	Trace	..	..
Na	265	182	512	30	119	1399
K	16	7	47	6	..	52
Ca	<i>Nil</i>	6	4	7	10	86
Mg	37	29	23	16	18	80
Fe	<i>Nil</i>	Trace	1	Trace	..	Trace
Al ₂ O ₃ (Fe ₂ O ₃)..	<i>Nil</i>	<i>Nil</i>	1	2	Trace	16
SiO ₂	42	45	97	21	9	15
Organic ..	<i>Nil</i>	<i>Nil</i>	Trace	<i>Nil</i>	..	<i>Nil</i>
Total Solids ..	902	682	1607	214	413	4279
Extra CO ₂ ..	..	57	..	..	..	..

B3751. Mud Spring, Loc. 3179, Arrowsmith River (H. 50).

Depth, 2 feet. Rock, Jurassic (?) sandstone with thin layer of Recent diatomite.

Reference: B. 38, p. 67.

B3752. Arrowsmith Spring, Reserve 973, Arrowsmith River (H. 50).

Depth, 3 feet. Rock, Jurassic (?) sandstone.

Reference: B. 38, p. 67.

B1839. Well, "North Spring," Loc. 89, Yandanooka (H. 50). Rock, Carboniferous (?) sandstone.

B3627. New Well, near railway, Arrino (H. 50).

Depth, 45 feet. Rock, Carboniferous (?) sandstone.

Tc. Stream water, Goldfields Water Supply Reservoir, Helena River, Mundaring (H. 50).

D4264. Artesian Bore, western corner of Loc. 38, Gosnells (H. 50).

Depth, 172 feet. Rock, Mesozoic sandstones and shales.

TABLE T.—*continued.*

G.S.L. No. ..	C1881.	C1873.	C1879.	C1880.	C1882.	C1883.
Source ..	Lockeridge Bore.	Padbury's No. 1 Bore.	Padbury's No. 2 Bore.	Butcher's Bore.	Munday's Bore.	Bebo-moro Bore.
Locality ..	Guildford.	Guildford.	Guildford.	Guildford.	Guildford.	Guildford.

SALTS—PARTS PER CENT.

CaCO ₃ ..	·0030	·0042	·0026	·0034	·0061	·0046
MgCO ₃ ..	·0052	·0058	·0044	·0046	·0038	·0054
FeCO ₃ ..	<i>Nil</i>	Min. tr.	<i>Nil</i>	<i>Nil</i>	Trace	Min. tr.
Na ₂ CO ₃ ..	·0055	·0027	·0041	·0060	..	·0048
MgSO ₄ ..	..	..	..	..	·0027	..
Na ₂ SO ₄ ..	·0023	·0016	·0019	·0029	..	·0023
K ₂ SO ₄ ..	·0005	·0007	·0022	·0022	..	·0007
NaNO ₃ ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
MgCl ₂ ..	..	..	..	..	·0012	..
NaCl ..	·0148	·0344	·0178	·0291	·0332	·0288
KCl ..	..	..	..	..	·0009	..
NaBr ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
NaI ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
Al ₂ O ₃ (Fe ₂ O ₃) ..	·0003	·0004	·0002	·0001	·0003	·0002
P ₂ O ₅ ..	Trace	<i>Nil</i>	Trace	Trace	<i>Nil</i>	Trace
SiO ₂ ..	·0027	·0018	·0021	·0019	·0021	·0018
Total Solids ..	·0343	·0516	·0353	·0500	·0503	·0486
Extra CO ₂ ..	·0063	·0074	·0073	·0078	·0047	·0096
H ₂ S ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
Analyst ..	H.B.	H.B.	J.H.B.	J.H.B.	H.B.	H.B.
Date ..	1908.	1908.	1908.	1908.	1908.	1908.

TABLE T.—*continued.*

G.S.L. No. ..	C1881.	C1873.	C1879.	C1880.	C1882.	C1883.
Locality ..	Guildford.	Guildford.	Guildford.	Guildford.	Guildford.	Guildford.
IONS—PARTS PER MILLION.						
Cl	90	209	108	177	215	175
SO ₄	19	15	25	31	22	20
CO ₃	86	81	70	87	64	93
PO ₄	Trace	Nil	Trace	Trace	Nil	Trace
Na	89	152	94	149	130	141
K	2	3	10	9	5	3
Ca	12	17	10	14	24	18
Mg	15	17	13	13	19	16
Fe	Nil	Trace	Nil	Nil	Trace	Trace
Al ₂ O ₃ (Fe ₂ O ₃) ..	3	4	2	1	3	2
SiO ₂	27	18	21	19	21	18
Total Solids ..	343	516	353	500	503	486
Extra CO ₂ ..	63	74	73	78	47	96

C1881. H. Hamersley's "Lockeridge" Artesian Bore, Swan Loc. P., Guildford (H. 50).

Depth, 798 feet. Supply, 120,000 gals. Rock, Tertiary and Mesozoic sandstones and shales.

C1873. Padbury's No. 1 Sub-artesian Bore, Lot 94, Sub-lot 27, Guildford (H. 50).

Depth, 240 feet. Rock, Tertiary and Mesozoic sandstones and shales.

C1879. Padbury's No. 2 Artesian Bore, Lot 94, Sub-lot 24, Guildford (H. 50).

Depth, 755 feet. Supply, 250,000 gals. per diem. Rock, same as C1873.

C1880. Butcher's Artesian Bore, Lot 94, Sub-lot 28, Guildford (H. 50).

Depth, 404 feet. Supply, 65,000 gals. per diem. Rock, same as C1873.

C1882. Munday's Artesian Bore, Lot 1, Market Street, Guildford (H. 50).

Depth, 340 feet. Supply, 74,000 gals. per diem. Temperature, 75deg. F. Rock, same as C1873.

C1883. Bebo-moro (Gull's) Artesian Bore, Lot 95, Guildford (H. 50).

Depth, 408 feet. Supply, 60,000 gals. per diem. Rock, same as C1873.

TABLE T.—*continued.*

G.S.L. No. ..	C1919.	C1924.	C6049.	Td.	C1850.	C2024.
Source ..	Municipal Bore.	Waterhall No. 2 Bore.	Smith's Swamp.	Wellington St. Bore.	Asylum Bore.	No. 1 Bore.
Locality ..	Guildford.	Guildford.	North Perth.	Perth.	Claremont.	Claremont.

SALTS—PARTS PER CENT.

CaCO ₃ ..	·0071	·0041	·0030	·0074	·0012	·0039
MgCO ₃ ..	·0026	·0023	·0036	·0014	·0038	·0054
FeCO ₃ ..	·0007	·0024	·0010	Trace	Trace	Min. tr.
Na ₂ CO ₃ ..	..	..	..	..	·0176	·0084
MgSO ₄ ..	·0120	·0067	·0006	·0025	..	..
Na ₂ SO ₄ ..	..	..	..	..	·0021	·0037
K ₂ SO ₄ ..	..	..	·0032	..	·0011	·0009
NaNO ₃ ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
MgCl ₂ ..	·0019	·0039	..	·0039	..	..
NaCl ..	·1028	·0670	·0219	·0375	·0585	·0797
KCl ..	·0010	·0019	·0004	·0021	..	..
NaBr ..	<i>Nil</i>	<i>Nil</i>	..	..	Min. tr.	<i>Nil</i>
NaI ..	<i>Nil</i>	<i>Nil</i>	..	..	<i>Nil</i>	<i>Nil</i>
Al ₂ O ₃ (Fe ₂ O ₃)..	·0006	·0005	·0002	·0008	·0004	·0002
P ₂ O ₅ ..	Trace	Trace	..	..	Trace	Min. tr.
SiO ₂ ..	·0028	·0027	·0019	·0020	·0012	·0020
Organic ..	<i>Nil</i>	<i>Nil</i>	·0033	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
Total Solids ..	0·1315	0·0915	0·0391	0·0576	0·0859	0·1042
Extra CO ₂ ..	·0057	·0074	..	..	·0096	·0092
H ₂ S ..	<i>Nil</i>	Trace	..	Trace (·00004)	<i>Nil</i>	<i>Nil</i>
Analyst ..	H.B.	H.B.	H.B.	E.S.S.	H.B.	H.B.
Date ..	1908.	1908.	1914.	1901.	1908.	1908.

TABLE T.—*continued.*

G.S.L. No. ..	C1919.	C1924.	D6049.	Td.	C1850.	C2024.
Locality ..	Guildford.	Guildford.	North Perth.	Perth.	Claremont.	Claremont.
IONS—PARTS PER MILLION.						
Cl	643	444	135	266	355	483
Br	<i>Nil</i>	<i>Nil</i>	..	..	Trace	<i>Nil</i>
SO ₄	96	53	23	20	20	30
CO ₃	66	55	49	54	134	109
PO ₄	Trace	Trace	..	..	Trace	Trace
Na	404	264	86	148	313	362
K	5	10	16	11	5	4
Ca	28	16	12	30	5	16
Mg	36	30	11	19	11	16
Fe	3	11	5	Trace	Trace	Trace
A ₂ O ₃ (Fe ₂ O ₃)..	6	5	2	8	4	2
SiO ₂	28	27	19	20	12	20
Organic ..	<i>Nil</i>	<i>Nil</i>	33	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
Total Solids ..	1315	915	391	576	859	1042
Extra CO ₂ ..	57	74	..	..	96	92
H ₂ S	<i>Nil</i>	Trace	..	Trace	<i>Nil</i>	<i>Nil</i>

C1919. Municipal Artesian Bore, Helena Street, Guildford (H. 50).

Depth, 1,202 feet. Supply, 1,000,000 gals. per diem. Rock, Tertiary and Mesozoic sandstones, mudstones, and shales.

C1924. Waterhall (Morrison's) No. 2 Artesian Bore, Loc. 7, Helena River, Guildford (H. 50).

Depth, 691 feet. Supply, 200,000 gals. per diem. Rock, same as C1919.

D6049. Shallow trenches on Smith's Swamp, North Perth (H. 50).

Rock, Recent infusorial (Ephydatia) earth surrounded by Tertiary sand dunes.

Td. Wellington Street Artesian Bore, Perth (H. 50).

Depth, 815 feet. Supply, 200,000 gals. per diem. Rock, same as C1919.

C1850. Artesian Bore, Hospital for the Insane, Claremont (H. 50).

Depth, 2,070 feet. Supply, 900,000 gals. per diem. Rock, Recent and Mesozoic sandstones, mudstones, shales, and limestones.

C2024. No. 1 Artesian Bore, Reserve 4228, Claremont (H. 50).

Depth, 1,506 feet. Supply, 560,000 gals. per diem. Rock, same as C1850.

TABLE T.—*continued.*

G.S.L. No. ..	Te.	C1851.	C1996.	B22.	Tl.	Tg.
Source ..	No. 2 Bore.	No. 2 Bore.	Show Ground Bore.	Well.	Bore.	Reservoir Bore Water.
Locality ..	Claremont.	Claremont.	Claremont.	Lower Canning.	Freemantle.	Freemantle.

SALTS—PARTS PER CENT.

H ₂ SO ₄ ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	·0048	<i>Nil</i>	<i>Nil</i>
CaCO ₃ ..	·0028	·0014	·0041	<i>Nil</i>	·0051	·0047
MgCO ₃ ..	·0007	·0038	·0052	<i>Nil</i>	·0043	·0055
FeCO ₃ ..	..	Trace	<i>Nil</i>	..	..	..
Na ₂ CO ₃ ..	·0170	·0174	·0082	..	..	..
CaSO ₄ ..	·0015	..	..	·0082	·0019	Trace
MgSO ₄ ..	·0007	..	..	·0060	·0041	·0013
Al ₂ (SO ₄) ₃ ..	..	..	..	·0120	..	..
Na ₂ SO ₄ ..	..	·0021	·0043	..	..	·0056
K ₂ SO ₄ ..	..	·0011	·0003	..	..	..
NaNO ₃ ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	..	..	min. tr.
MgCl ₂ ..	..	..	..	·0074	·0007	..
NaCl ..	·0585	·0576	·0818	·0239	·0751	·0805
KCl ..	..	..	..	..	..	·0031
NaBr ..	..	min. tr.	<i>Nil</i>	..	..	..
NaI ..	..	<i>Nil</i>	<i>Nil</i>	..	..	..
Al ₂ O ₃ (Fe ₂ O ₃) ..	·0006	·0002	·0001	..	·0003	·0001
P ₂ O ₅ ..	..	Trace	<i>Nil</i>	..	..	..
SiO ₂ ..	·0021	·0016	·0019	·0022	·0024	·0018
Total Solids ..	0·0839	0·0852	0·1059	0·0645	0·0939	0·1026
Extra CO ₂ ..	..	·0086	·0093	..	..	..
Analyst ..	Govt. Analyst	H.B.	H.B.	J.H.B.	Govt. Analyst	Govt. Analyst
Date ..	1906	1908	1908	1904	1902	1906

TABLE T.—*continued.*

G.S.L. No. ..	Te.	C1851.	C1996.	B22.	Tf.	Tg.
Locality ..	Claremont.	Claremont.	Claremont.	Lower Canning.	Fremantle.	Fremantle.
H	..	..	..	1 ¹	..	..
Cl	355	349	496	200	461	503
Br	..	Trace	Nil	..	..	..
SO ₄	17	20	31	254	46	48
CO ₃	118	134	108	..	62	67
NO ₃	Nil	Nil	Nil	..	..	Trace
PO ₄	..	Trace	Nil	..	..	..
Na	304	309	372	94	295	335
K	..	5	1	..	..	16
Ca	15	6	16	24	26	19
Mg	3	11	15	31	22	19
Fe	..	Trace	Nil	..	..	..
Al	..	..	..	19	..	..
Al ₂ O ₃ (Fe ₂ O ₃) ..	6	2	1	..	3	1
SiO ₂	21	16	19	22	24	18
Total Solids ..	839	852	1059	645	939	1026
Extra CO ₂ ..	..	86	93	..	..	..

¹ More exactly, 0·98.**Te and C1881.** No. 2 Artesian Bore, Claremont (H. 50).

Depth, 1,943 feet. Supply, 1,000,000 gals. per diem. Temperature, 104deg. F. Rock, Tertiary and Mesozoic sandstones, mudstones, shales, and limestones.

C1996. Agricultural Show Ground Bore, Claremont (H. 50).

Depth, 1,500 feet. Supply, 300,000 gals. per diem. Rock, same as C1851.

B22. Well, Lower Canning River, Applecross (H. 50).**Tf.** Artesian Bore, Fremantle (I. 50).**Tg.** Artesian Bore Water from Reservoir, Fremantle (I. 50).

TABLE T.—*continued*.

G.S.L. No. ..	C1884.	C1878.	D5464.	A3770.	D525.	B2650.
Source ..	No. 1 Bore.	No. 2 Bore.	Dam.	Gold Mine.	Well.	Mt. Benson Mine.
Locality ..	Fre- mantle.	Fre- mantle.	Wagin.	Donny- brook.	Jarnadup.	Ravens- thorpe.

SALTS—PARTS PER CENT.

CaCO ₃ ..	·0037	·0024	·0046	·0152	·0059	·0571
MgCO ₃ ..	·0083	·0085	..	·0095	·0059	..
FeCO ₃ ..	·0011	·0005	..	..	·0003	..
Na ₂ CO ₃ ..	..	·0014	..	..	..	..
CaSO ₄ ..	..	..	·2025	..	..	·0243
MgSO ₄ ..	..	..	..	·0029	·0009	·1608
Na ₂ SO ₄ ..	·0062	·0065	..	..	..	..
K ₂ SO ₄ ..	·0013	·0007	..	..	..	..
NaNO ₃ ..	<i>Nil</i>	<i>Nil</i>	..	..	<i>Nil</i>	<i>Nil</i>
CaCl ₂ ..	..	..	·0170	..	..	..
MgCl ₂ ..	..	..	·2379	·0188	·0039	·1631
NaCl ..	·0759	·0833	1·1962	·0718	·0322	1·1923
KCl ..	..	..	..	..	·0015	..
NaBr ..	<i>Nil</i>	<i>Nil</i>	..	..	<i>Nil</i>	..
NaI ..	<i>Nil</i>	<i>Nil</i>	..	..	<i>Nil</i>	..
Al ₂ O ₃ (Fe ₂ O ₃) ..	·0004	·0004	·0013	·0007	·0006	·0005
P ₂ O ₅ ..	<i>Nil</i>	<i>Nil</i>	..	..	<i>Nil</i>	..
SiO ₂ ..	·0021	·0020	·0009	·0045	·0016	·0030
Total Solids ..	0·0990	0·1057	1·6604	0·1234	0·0528	1·6011
Extra CO ₂ ..	·0077	·0066	..	..	..	..
H ₂ S ..	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
Analyst ..	H.B.	H.B.	A.J.R.	E.S.S.	H.B.	E.S.S.
Date ..	1908	1908	1914	1902	1911	1906

TABLE T.—*continued.*

G.S.L. No. ..	C1884.	C1878.	D5464.	D3770.	D525.	B2650.
Locality ..	Fremantle.	Fremantle.	Wagin.	Donnybrook.	Jarnadup.	Ravensthorpe.

IONS—PARTS PER MILLION.

Cl	460	506	9137	576	231	8447
SO ₄	49	48	1429	23	7	1454
CO ₃	87	85	28	159	79	342
Na	319	354	4705	282	127	4690
K	6	3	..	..	8	..
Ca	15	10	675	61	24	301
Mg	24	25	608	81	29	742
Fe	5	2	..	..	1	..
Al ₃ O ₃ (Fe ₂ O ₃) ..	4	4	13	7	6	5
SiO ₂	21	20	9	45	16	30
Total Solids ..	990	1057	16604	1234	528	16011

C1884. No. 1 Sub-artesian Bore, Hampton Road, Fremantle (I. 50).

Depth, 456 feet. Supply, 500,000 gals. per diem (pumped). Temperature, 80deg. Rock, Tertiary and Mesozoic sandstones, shales, and limestones.

C1878. No. 2 Artesian Bore, Hampton Road, Fremantle (I. 50).

Depth, 1,322 feet. Supply, 1,000,000 gals. per diem. Rock, same as C1884.

D5464. Surface water, Dam, Wagin (I. 50).

A3770. Gold Mine, Donnybrook (I. 50).

Rock, sandstone overlying granite.

D525. Well, two miles west of Darnadup (I. 50).

Depth, 12 feet.

B2650. Mt. Benson Copper-Gold Mine, M.L. 175, Ravensthorpe (I. 51).

Rock, contact of greenstone and granite.

TABLE T.—concluded.

G.S.L. No. ..	B885.	C1186.	C1834.	C2068.	B3095.	B3096.
Source ..	Cordingup Well.	Medic Mine.	Flag Mine.	Flag Mine.	No. 1 Spring.	No. 2 Spring.
Locality ..	Ravens-thorpe.	Kundip.	Kundip.	Kundip.	Jerda-cuttup. River.	Jerda-cuttup. River.

SALTS—PARTS PER CENT.

CaCO ₃	·0125	·0482	·0553	·0595	·0013	·0011
MgCO ₃	·0233	..	·0084	·0015	·0004	·0003
FeCO ₃	·0001	Trace	Trace	<i>Nil</i>	..	..
CaSO ₄	..	·0470	..	..	..	..
MgSO ₄	·0204	·3275	·1910	·2016	·0056	·0056
NaNO ₃	Min. Tr.	<i>Nil</i>	<i>Nil</i>	Trace	<i>Nil</i>	<i>Nil</i>
MgCl ₂	·0153	·4088	·1627	·1896	·0062	·0051
NaCl	·1863	2·5882	1·3485	1·3742	·0568	·0573
KCl	·0032	..	·0198	·0129	..	..
NaBr	..	..	·0002	·0002	..	..
NaI	..	..	<i>Nil</i>	<i>Nil</i>	..	..
Al ₂ O ₃ (Fe ₂ O ₃) ..	·0003	·0030	·0014	·0038	·0005	Trace
SiO ₂	·0021	·0032	·0024	·0026	·0027	·0029
Total Solids ..	0·2635	3·4259	1·7897	1·8459	0·0735	0·0723
H ₂ S	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	Trace	Trace
Analyst	E.S.S.	C.C.W.	H.B.	H.B.	C.C.W.	C.C.W.
Date	1905	1908	1908	1908	1907	1907

TABLE T.—concluded.

G.S.L. No. ..	B885.	C1186.	C1834.	C2068.	B3095.	B3096.
Locality ..	Ravensthorpe.	Kundip.	Kundip.	Kundip.	Jerdacuttup River.	Jerdacuttup River.

IONS—PARTS PER MILLION.

Cl	1259	18744	9485	9809	391	386
Br	..	..	1	1	..	..
SO ₄	163	2951	1490	1609	45	45
CO ₃	242	289	392	368	11	9
NO ₃	Trace	<i>Nil</i>	<i>Nil</i>	Trace	<i>Nil</i>	<i>Nil</i>
Na	733	10182	5306	5407	223	225
K	17	..	104	68	..	..
Ca	50	331	221	238	5	4
Mg	147	1700	860	895	28	25
Fe	Trace	Trace	Trace	<i>Nil</i>	..	..
Al ₂ O ₃ (Fe ₂ O ₃) ..	3	30	14	38	5	Trace
SiO ₂	21	32	24	26	27	29
Total Solids ..	2635	34259	17897	18459	735	723

B885. Cordingup Well, Ravensthorpe (I. 51).

Rock, soda-granite with greenstone dykes.

C1186. Main shaft, Medic Gold Mine, G.M.L. 66, Kundip (I. 51).

Depth, 170 feet; water level, 80 feet. Rock, greenstone.

C1834 and **C2068.** Main shaft, Flag Gold-Copper Mine, G.M.L. 137, Kundip (I. 51).

Depth, 200 feet; water level, 100 feet. Supply, 60,000 gals. per diem. Rock, greenstone.

B3095. No. 1 Spring, Jerdacuttup River, east of Kundip (I. 51).

B3096. No. 2 Spring, Jerdacuttup River, east of Kundip (I. 51).

TABLE U.—WATERS—EUCLA DIVISION.

G.S.L. No. ..	D1500.	B337.	A864.	B636.	B329.	B374.
Source ..	Venture Mine.	Well W.R. 160.	Lake Cowan.	Lady Mary North Mine.	Well W.R. 146.	Well W.R. 169.
Locality ..	Norseman.	Norseman.	Norseman.	Norseman.	Norseman.	Norseman.

SALTS—PARTS PER CENT.

CaCO ₃ ..	Trace	·0107	·0076	·0683	·0365	·0450
MgCO ₃ ..	..	·0572	..	..	·0291	·0180
Na ₂ CO ₃ ..	..	·0380	..	..	..	..
CaSO ₄ ..	·192	..	·2238	·0325	..	..
MgSO ₄ ..	·092	..	1·1324	·1836	·1037	·0527
NaSO ₄ ..	..	·0458	..	..	..	..
K ₂ SO ₄ ..	..	·0048	..	..	..	..
NaNO ₃ ..	<i>Nil</i>	..	..	Trace	..	..
MgCl ₂ ..	·737	..	3·1905	·1328	·0222	·1368
NaCl ..	3·760	·5236	18·8806	1·0183	·5427	·4943
KCl ..	·015	..	·0738	·0101	·0105	·0049
Al ₂ O ₃ (Fe ₂ O ₃) ..	·035	Trace	·0044	·0012	Trace	Trace
SiO ₂ ..	·010	·0038	Trace	·0072	·0052	·0094
Total Solids ..	4·841	0·6839	23·5131	1·4540	0·7499	0·7611
Analyst ..	H.B.	J.H.B.	E.S.S.	J.H.B.	J.H.B.	J.H.B.
Date ..	1911	1904	1898	1905	1904	1904

TABLE U.—*continued.*

G.S.L. No. ..	D1530.	B337.	A864.	B636.	B329.	B374.
Locality ..	Norseman.	Norseman.	Norseman.	Norseman.	Norseman.	Norseman.
IONS—PARTS, PER MILLION.						
Cl	28367	3176	138638	7214	3507	4040
SO ₄	2089	336	10616	1694	828	421
CO ₃	Trace	686	46	410	426	398
NO ₃	Nil	..	..	Trace	..	..
Na	14792	2373	74276	4006	2135	1945
K	79	22	387	53	55	26
Ca	565	43	689	369	146	180
Mg	2068	165	10435	710	350	507
Al ₂ O ₃ (Fe ₂ O ₃) ..	350	Trace	44	12	Trace	Trace
SiO ₂	100	38	Trace	72	52	94
Total Solids ..	48410	6839	235131	14540	7499	7611

D1500. Venture Gold Mine, G.M.L. 887, Norseman (I. 51).
Rock, amphibolite.

B337. Well on Water Right 160, Norseman (I. 51).

A864. Trenches on Lake Cowan, Norseman (I. 51).
Rock, mud with gypsum.

B636. Lady Mary North Gold Mine, Norseman (I. 51).
Rock, greenstone schist and jasper.

B329. Well on Water Right 146, Norseman (I. 51).
Rock, greenstone schist and jasper.

B374. Well on Water Right 168, Norseman (I. 51).
Rock, norite.

TABLE U.—concluded.

G.S.L. No. ..	B368.	A863.	D1499.	Ua.	Ub.	Uc.
Source ..	Well W.R. 167.	Lake Cowan.	Trenches ?	No. 1 Bore.	No. 2 Bore.	No. 3 Bore.
Locality ..	Princess Royal.	Princess Royal.	Lake Cowan.	Madura.	Nullarbor.	Trans- Austra- lian Railway.

SALTS—PARTS PER CENT.

CaCO ₃ ..	·0223	·0092	Trace	·0278	·0142	·0091
MgCO ₃ ..	·0359	..	..	·0048	·0130	·0076
FeCO ₃ ..	..	Trace	..	..	..	..
Na ₂ CO ₃ ..	..	..	..	..	..	·0238
CaSO ₄ ..	..	·5393	·232	·0153	·1119	..
MgSO ₄ ..	·0267	·3417	·877	·0069	·0622	..
Na ₂ SO ₄ ..	..	..	..	..	..	·0770
MgCl ₂ ..	·0262	1·5362	2·049	..	·0613	..
NaCl ..	·1502	10·4901	16·170	·7094	·6999	·2021
KCl ..	·0034	·0513	·205	..	..	..
NaI ..	..	Trace	..	..	..	..
Al ₂ O ₃ (Fe ₂ O ₃) ..	Trace	·0058	·010	Trace	Trace	·0008
SiO ₂ ..	·0077	Trace	·003	·0028	·0006	·0006
Total Solids ..	0·2724	12·9736	19·546	0·7670	0·9631	0·3210
Analyst ..	J.H.B.	E.S.S.	H.B.	Govt. Analyst.	Govt. Analyst.	Govt. Analyst.
Date ..	1904	1898	1911	1904	1911	1911

TABLE U.—*concluded.*

G.S.L. No. ..	B368.	A863.	D1499.	Ua.	Ub.	Uc.
Locality ..	Princess Royal.	Princess Royal.	Lake Cowan.	Madura.	Nullarbor.	Trans-Australian Railway.

IONS—PARTS PER MILLION.

Cl	1123	75316	114319	4303	4702	1226
I	..	Trace	..	..	..	..
SO ₄	213	6533	8646	163	1286	521
CO ₃	390	55	Trace	201	178	244
Na	590	41268	63613	2791	2753	1147
K	18	269	1075	..	..	..
Ca	89	1624	683	156	386	36
Mg	224	4613	6994	28	320	22
Fe	..	Trace	..	..	..	..
Al ₂ O ₃ (Fe ₂ O ₃) ..	Trace	58	100	Trace	Trace	8
SiO ₂	77	Trace	30	28	6	6
Total Solids ..	2724	129736	195460	7670	9631	3210

B368. Well on W.R. 167, Princess Royal (I. 51).

Depth, 100 feet. Rock, amphibolite close to norite.

A863. Trenches on Lake Cowan, Princess Royal (I. 51).

Rock, mud with gypsum.

D1499. Trenches (?), Lake Cowan (I. 51).

Rock, mud with gypsum.

Ua. No. 1 Artesian Bore, Loc. 149/95, Madura, 45 miles N.E. of Eyre (H. 52).

Depth, 2,101 feet. Supply, 30,000 gals. per diem. Rock, Tertiary limestone and Mesozoic mudstone and limestone.

Ub. No. 2 Bore (sub-artesian). Nullarbor Plains, 30 miles north of Madura (H. 52).

Depth, 430 feet. Rock, Tertiary limestone.

Uc. No. 3 Bore (sub-artesian). 337 miles 61 chains on Trans-Australian Railway (H. 52).

Depth, 1,370 feet. Rock, Tertiary limestone and Mesozoic mudstone and sandstone.

INDEX.

	Page
<i>Adamellose</i>	21
<i>Akerose</i>	23, 27
<i>Alaskose</i>	17, 19
<i>Almerose</i>	17
<i>Amadorose</i>	21
<i>Amphibolite</i>	24, 26, 32, 34, 36, 41, 54, 58, 62, 64, 70, 72
<i>Andalusite schist</i>	96
<i>Andesite</i>	50
<i>Andose</i>	23, 27
<i>Arkose</i>	102
<i>Arrino</i>	104, 172
<i>Arrowsmith River</i>	172
<i>Australite</i>	16, 135
<i>Auvergnose</i>	3, 25, 27, 29, 31, 33, 35, 37
Baker's Hill	122
<i>Ballinoo meteorite</i>	136
<i>Bamboo Creek</i>	38, 48
<i>Bandose</i>	27
<i>Bangemall</i>	38, 68, 80, 92, 96
<i>Bannister</i>	18
<i>Basalt</i>	22, 24, 49, 50
<i>Beerbachose</i>	27, 31
<i>Bellevue</i>	104, 105, 106
<i>Belmont</i>	106
<i>Binduli</i>	42, 44, 62, 96, 102
<i>Bingie Bintie</i>	164
<i>Biotite schist</i>	64
<i>Bituminous coal</i>	108-114
<i>Black Range</i>	156
<i>Boogardie</i>	118, 154
<i>Boolathanna</i>	108
<i>Box Soak</i>	48, 68
<i>Brown Coal</i>	109, 110
<i>Brown coal shale</i>	109, 110
<i>Bullsbrook</i>	86
<i>Bulong</i>	115
<i>Burtville</i>	158
<i>Busselton</i>	86, 99
Calc. schist	60, 74
<i>Camptonose</i>	23, 25, 33, 35

INDEX—*continued.*

	Page
Canning River.. .. .	178
Cape Arid	98
Cape Riche	99
Carbonated amphibolite	54, 68, 70
Carbonated peridotite	67, 68, 76, 78
Carbonated propylite	74
Carbonate rocks	80-95
Carnarvon	146
Cavanagh Range	30
Ceratophyre	14, 16, 18, 20, 40, 42, 44, 60
Chalk	84, 86
Charnley River	46
Chlorite schist	41, 48, 50, 66, 70, 74, 117
Chloritoid schist	60
Claremont	176, 178
Clay	104, 105, 106
Cliffy Head	109
Coal	108-114
Coal ashes	114
Coal shale	108-111
Collie	106, 110-114
Comet Vale	118
Cone Bay	146
Cookose	31
Coolgardie	16, 36, 78, 108, 120, 166
Coorara Claypan	90
Corsase	33, 35
Cue	14, 20, 24, 32, 34, 38, 52, 152
Dacose	17, 21
Dardanup	109
Darlot	156
Day Dawn	52
Dead Finish	38, 90
Denmark	88
Diatomite	98
Diorite	64
Dolerite .. 22, 32, 34, 36, 46, 49, 51, 53, 55, 57, 59, 61, 63, 65, 67, 69, 71, 73, 75, 79	
Dolomite	90, 92, 94
Dolomite marble	90, 92
Dongara	82, 83, 84, 102, 109, 168
Donnelly River	115, 116, 117
Donnybrook	99, 109, 180
Duffers Creek	14
Duketon ¹⁾	156
Dune sand	82, 83, 84, 86, 99

INDEX—continued.

	Page
Eelogite	64
Edjudina	40, 126, 128
Egina	100
Epidiorite	24, 28, 32, 34, 36, 46, 48, 50, 52, 54, 56, 58
Epidosite	46, 66
Eradu	108
Fitzgerald River	110
Flybrook	110
Fremantle	178, 180
Gabanintha	70, 148
Gabbro	34, 53, 55, 73
Garden Gully	152
Gascoyne River	90
Gibbsite Laterite	123
Gibraltar	28, 62
Gingin	84, 86
Glen Forrest	28, 122
Gneiss	40, 54, 62
Goddard's Creek	94
Gold Ore	57, 102
Gooseberry Hill	122
Gosnells	172
Granite	16, 18, 20, 41, 44, 118
Granodiorite	20, 53, 55
Graphite rocks	52, 54, 78, 115, 116, 117
Graphitic clay	116, 117
Graphitic ironstone	115
Graphitic schist	52, 54, 78, 115, 116
Greenstone	40
Greenstone schist	40, 54
Guildford	174, 176
Haematite quartzite	124, 126, 128, 130
Haematite quartz rocks	124-131
Haematite rock	124, 126, 128
Hamersley meteorite	138
Hamersley Range	80
Hannans Lake	166
Hayes New Find	165
Hells Gates	24
Hessose	27, 29, 31, 35
Hogan's Find	128
Hornblende gneiss	62
Hornblende schist	28, 64, 66, 78
Hypersthenite	30

INDEX—*continued*.

	Page
Igneous rocks	9-37
Irregully Creek	32, 92
Irwin	168
Irwin River	108, 170
Isdell River	46
Jarnadup	180
Jarrahdene	88
Jasper	126
Jerdacuttup River	182
Kalgoorlie	16, 26, 34, 36, 42, 58, 60, 70, 72, 74, 76, 96, 120, 164
Kanowna	16, 70, 102
Kendenup	117
<i>Kilavose</i>	23
Kirrup	115
<i>Koghose</i>	27, 29
Kookynie	20, 160
Koolyanobbing	128
Kununoppin	82
Kundip	182
Lake Clifton	86
Lake Cowan	186
Lake Preston	86
<i>Lamarose</i>	23
<i>Lassenose</i>	15, 17
Laterised granite	118
Laterite	118-123
Lava	38, 48
Laverton	24
Lennonville	152
Leonora	26, 40, 54, 70, 96, 158
Lignite	108
Limestone	86, 38
Limonite laterite	119, 121
Lindsays	164
<i>Liparose</i>	17, 19
Liverynga	108
Lockier	170
Lockyers Gap	50
Madura	186
<i>Magdeburgose</i>	15
Magnesite schist	66
Magnetite quartzite	130
Mahogany Creek	18
Malcolm	54
Maninga Marley	156
Manjimup	115

INDEX—*continued*.

	Page
Marble	80, 90
Marble Bar	146
Marda	44, 78, 166
<i>Mariposose</i>	21
Marl	86, 94
Meekatharra	20, 38, 52, 68, 143, 148, 150
Menzies	162
Metasomatic igneous rocks	38-79
Meteorites	135-140
Mingenew	170
Mingenew, East	170
Monger Creek	46
Moolyella	20
Mooranoppin meteorite	136
Mosquito Creek	20
Mt. Anketell	50
Mt. Dooling meteorite	138
Mt. Edgar	22
Mt. Edith	124, 140
Mt. Edith meteorites.. .. .	135, 140
Mt. Egerton	100
Mt. Erin	154
Mt. Hale	124
Mt. Holmes	34
Mt. Hunt	164
Mt. Ida.. .. .	158, 160
Mt. Jackson	64
Mt. Lyell	32
Mt. Mason	126
Mt. Monger	42, 56
Mt. Narryer	124
Mt. Russell	92
Mt. Stirling meteorite	136
Mt. Stuart	124
Mt. Taylor	52
Mujar	106
Mulgarrie	164
Mulline	162
Mulwarrie	162
Mundaring	172
<i>Murchisonose</i>	25, 35
Napier Broome Bay	66
Newlands	106
Niagara	14, 16, 40, 54, 160
Norite	24, 26, 30, 118
Nornalup Inlet	110
Norseman	18, 30, 36, 44, 64, 94, 96, 130, 184

INDEX—continued.

									Page
Northampton ..	..	..	..	..	..	..	..	..	115
North Perth ..	..	..	..	..	..	..	..	..	176
North Pole ..	..	..	..	..	..	..	..	..	48
Noyangose ..	..	..	..	..	..	..	..	..	15, 17, 19
Nuleri meteorite	..	..	..	..	..	..	..	..	138
Nullagine ..	..	..	..	..	..	..	..	..	46, 146
Nullarbor Plains	..	..	..	..	..	..	..	..	88, 186
Omeose ..	..	..	..	..	..	..	..	..	17
Ora Banda ..	..	..	..	..	..	..	..	26, 54, 56, 70, 118	
Oruose ..	..	..	..	..	..	..	..	..	29, 31
Ouenose ..	..	..	..	..	..	..	..	..	27, 33, 37
Paynesville ..	..	..	..	..	..	..	..	..	154
Peawah ..	..	..	..	..	..	..	..	..	50
Pegmatite ..	..	..	..	..	..	..	..	..	14, 16, 20
Pelican Hill ..	..	..	..	..	..	..	..	..	146
Peridotite ..	..	..	..	..	..	..	53, 55, 67, 68, 71, 76, 78		
Perth ..	..	..	..	..	..	..	..	..	176
Phyllite ..	..	..	..	..	..	..	..	..	100, 102
Pig Well ..	..	..	..	..	..	..	..	..	158
Pingin ..	..	..	..	..	..	..	..	..	162
Placerose ..	..	..	..	..	..	..	..	..	21
Poona ..	..	..	..	..	..	..	..	..	32
Porphyrite ..	..	..	..	..	..	20, 22, 26, 42, 50, 56, 60, 62			
Porphyry ..	..	..	..	..	..	..	..	14, 38, 40, 44	
Premier Downs meteorites	..	..	..	..	..	..	..	135, 138	
Prince Regent River	..	..	..	..	..	..	..	..	22
Princess Royal ..	..	..	..	..	..	..	..	..	186
Propylite ..	..	..	..	..	..	..	..	48, 58, 60, 68, 72	
Pyroxenite ..	..	..	..	..	..	..	..	..	55, 67, 71
Quartz schist ..	..	..	..	..	..	..	..	..	96
Rafferty's Patch	..	..	..	..	..	..	..	..	156
Randells ..	..	..	..	..	..	..	..	..	166
Ravensthorpe ..	..	..	..	..	..	..	18, 20, 44, 64, 180, 182		
Rockingham ..	..	..	..	..	..	..	..	..	86, 94
Rosswineose ..	..	..	..	..	..	..	..	..	79
Sand ..	..	..	..	..	..	..	..	82, 83, 84, 86, 99	
Sandstone (rock) ..	..	..	..	..	..	..	..	..	96, 99
sandstone (town)	..	..	..	..	..	..	..	40, 52, 54, 70, 126	
Sandy Creek ..	..	..	..	..	..	..	..	..	146
Secret Creek ..	..	..	..	..	..	..	..	..	22, 90
Sedimentary rocks	..	..	..	..	..	..	..	..	80-114

INDEX—*continued*.

	Page
Sericite schist	102
Serpentine	38, 68, 70, 76
Shale	102, 106
Sherlock River	50
Silicified rock	38
Slate	96, 100, 117
Smith's Mill	28, 122
Soanesville	68
Soda granite	16, 20, 41, 44
Soda pegmatite	14, 20
Southern Cross	16, 28, 36, 62, 78, 80, 82, 102, 128, 130, 166
Station Peak	50
Strawberry	168
Subiaco	86
Synnott Creek	22, 46
Synnott Tableland	100
Tachylite	32
Talc-chlorite schist	54, 66, 70, 76
Talc rock	52
Talc schist	52
<i>Taurose</i>	19
<i>Tehamose</i>	15
<i>Tonalose</i>	21, 25
<i>Toscanose</i>	19
Tourmaline rock	62
Transcontinental Railway	186
Travertine	80, 82
Tuff	104
<i>Tuolumnose</i>	21
Turgite laterite	119, 121, 123
Uaroo	100
Vosperton	164
Wagin	180
Wanneroo	98
Warrawoona	46, 48, 66, 68, 90
Waters	143-160
<i>Wehrlose</i>	79
Westonia	62, 64, 78
<i>Westphalose</i>	15
Whim Creek	100
Willow Gully	154
Wiluna	156

INDEX—*continued.*

	Page
Wongan Hills	122
Wyndham	22, 108
Yampi Island	124
Yandanooka	172
Yarra Yarra Creek	38
Yarri	34, 162
<i>Yellowstonose</i>	21
Youndegin meteorite	135, 136
Yundamindera.. .. .	160

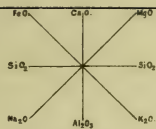
PLATES I. - X.

Brögger-Hobbs' Diagrams

of Rocks

in Tables A, B, C, and D.

TABLE A.



CERATOPHYRE }
LASSENSE }

DUFFERS CREEK. 5392

CERATOPHYRE }
LASSENSE }

CUE 3797

PORPHYRY }
MAGDEBURGOSE }

NIAGARA 13484

PORPHYRY }
TEHAMOSE }

NIAGARA 13502

SODA-PEGMATITE }
NOYANGOSE }

NIAGARA 13496

PEGMATITE }
QMEOSE }

NIAGARA 13499

SODA-GRANITE }
LASSENSE }

COOLGARDIE 5531

AUSTRALITE }
ALMEROSE }

KALGOORLIE 1853

TABLE A.

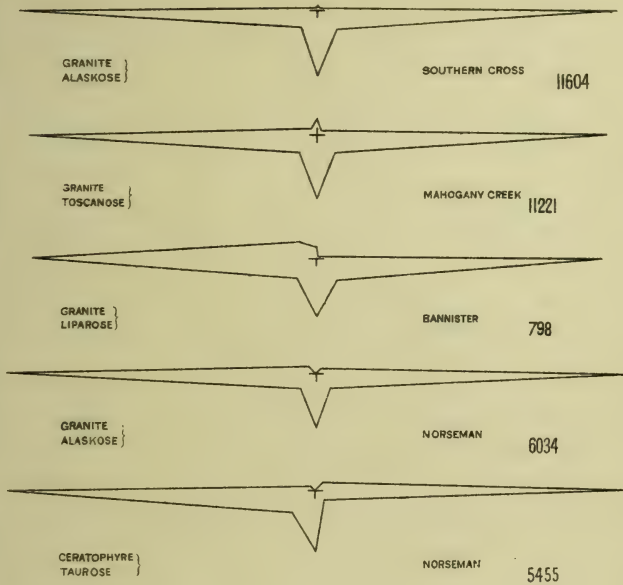
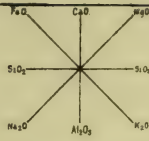
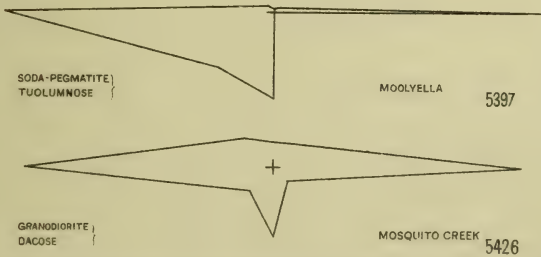


TABLE B.



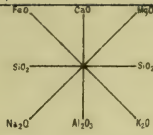


TABLE B.

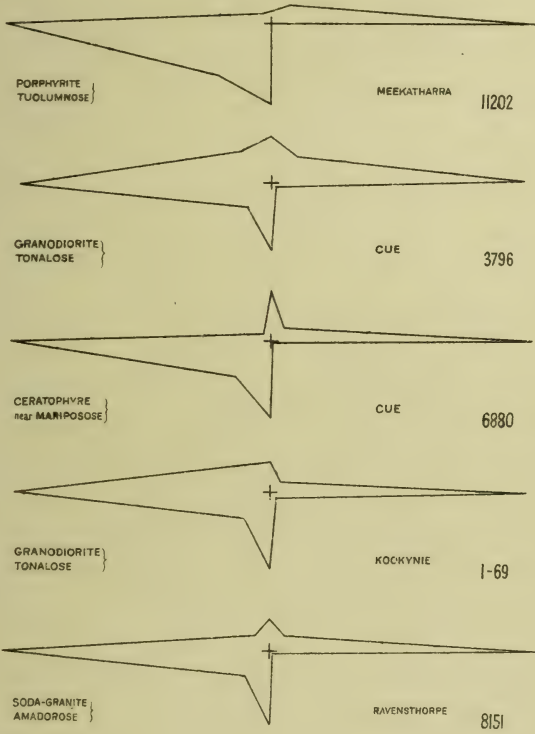
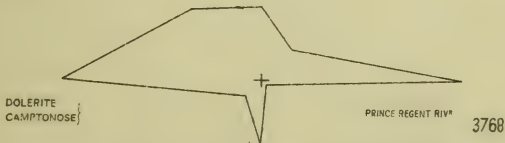
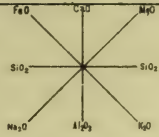


TABLE C.



Handwritten signature

TABLE C.

DOLERITE
CAMPTONOSE }

SYNNOTT CREEK.

3751

BASALT
KILAUESE }

WYNDHAM

3779

PORPHYRITE
AKEROSE }

M'EDGAR

5753

DOLERITE
CAMPTONOSE }

SECRET CREEK.

7616

EPIDIORITE
AUVERGNOSE }

CUE

6858

NORITE
AUVERGNOSE }

CUE

3832

H.P.

TABLE C.

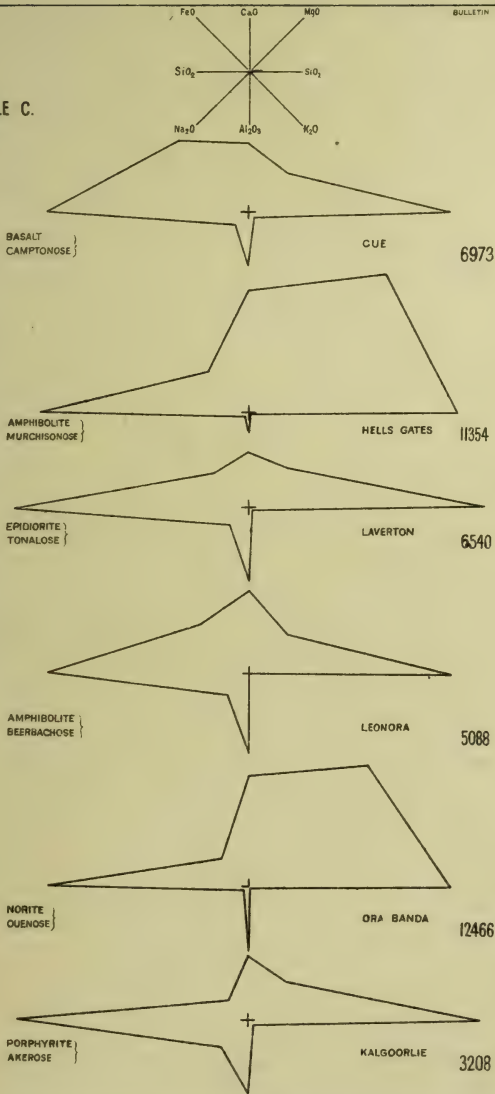


TABLE C.

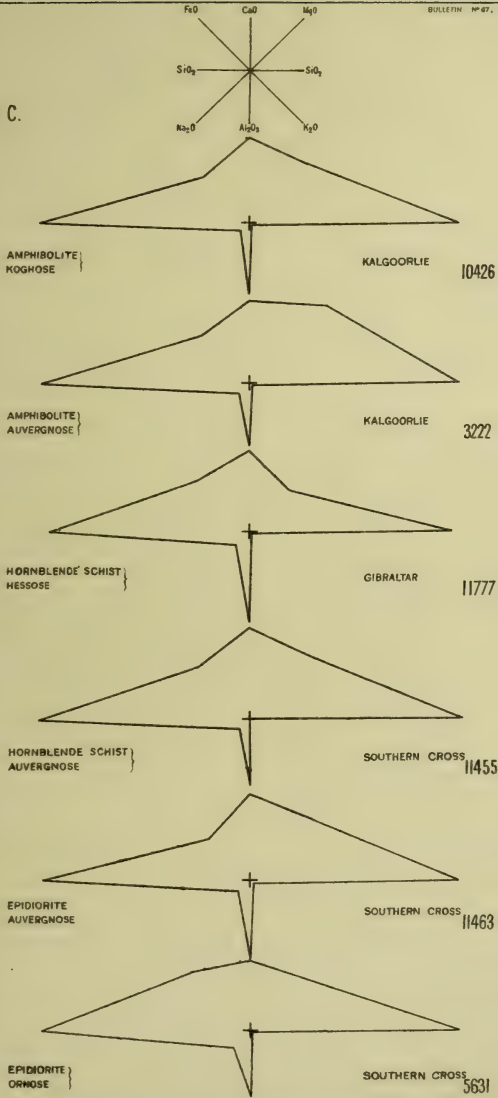


TABLE C.

BULLETIN N° 67, PLATE V D.

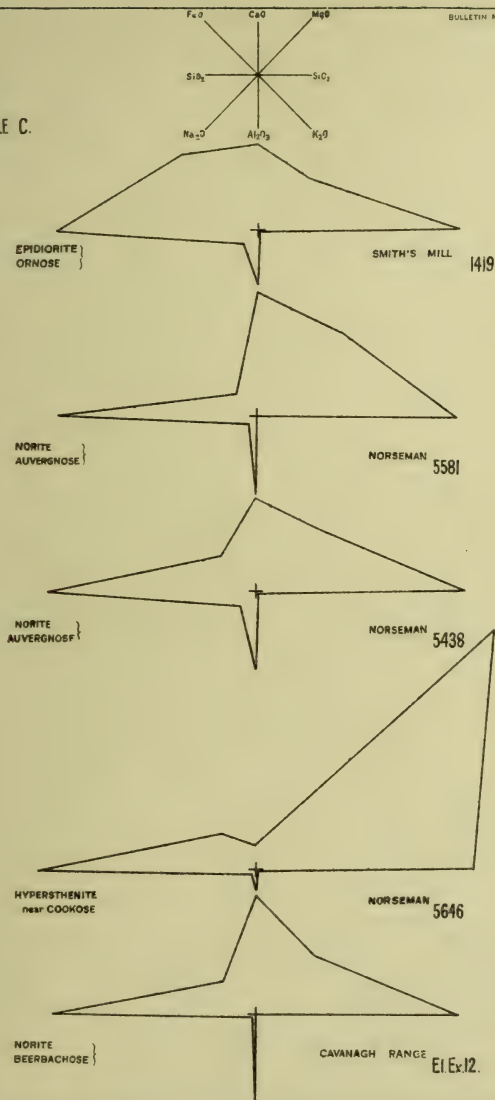
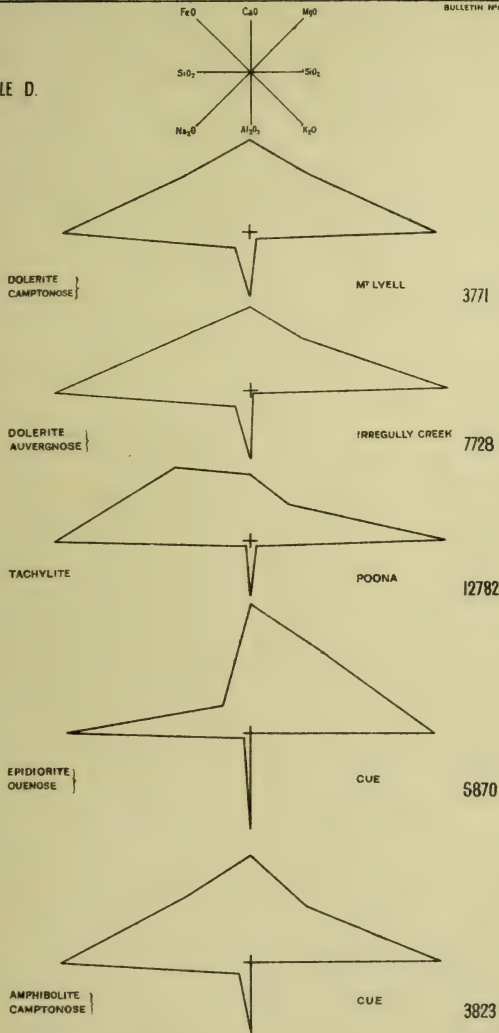


TABLE D.



Handwritten signature/initials

TABLE D.

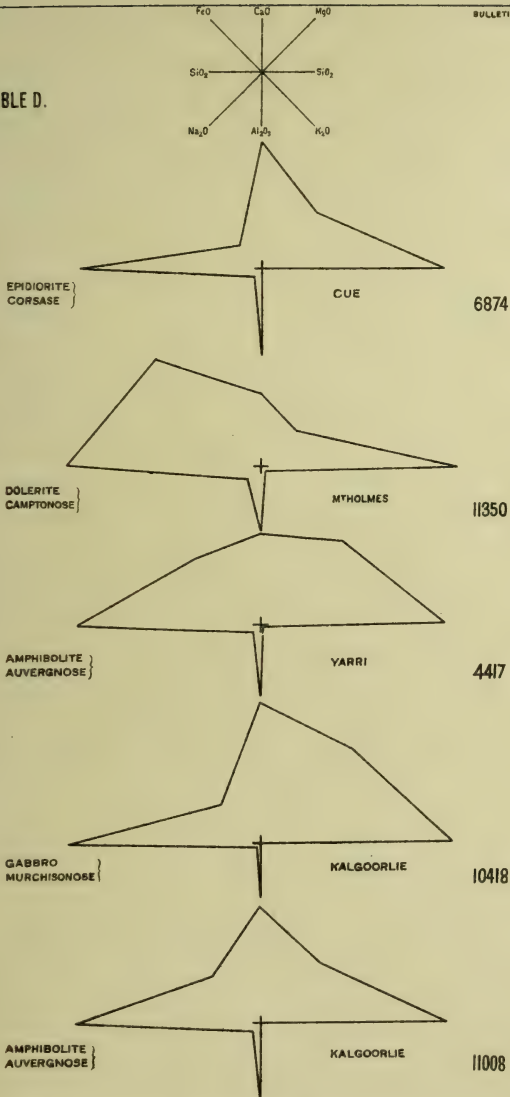


TABLE D.



EPIDIORITE
AUVERGNOSE }

KALGOORLIE

3231

EPIDIORITE
AUVERGNOSE }

KALGOORLIE

3306

AMPHIBOLITE
AUVERGNOSE }

COOLGARDIE

122

EPIDIORITE
OUENOSE }

SOUTHERN CROSS

11461

DOLERITE
AUVERGNOSE }

NORSEMAN

6119

EPIDIORITE
OUENOSE }

NORSEMAN

5999

GEOLOGICAL MAPS, REPORTS, AND BULLETINS

ISSUED BY

The Geological Survey of Western Australia.

I.—MAPS.

- Geological Map of Northampton : by A. Gibb Maitland. Scale, 20 chains per inch. Two sheets. Price, 2s. 6d. 1898.
- Geological Map of the North Lead, Kanowna : by Torrington Blatchford. Scale, 8 chains per inch. Price, 1s. 1901.
- Geological Map of Kalgoorlie : by A. Gibb Maitland and W. D. Campbell. Scale, 10 chains per inch. Six sheets. Price, 21s. 1902.
- In preparation :*
Geological Sketch Map of Western Australia : by A. Gibb Maitland. Scale, 1/1,584,000 Four sheets.

II.—REPORTS.

- Reports by the Government Geologist in connection with the Water Supply of the Gold-fields, containing—(a.) Coolgardie and Kalgoorlie ; (b.) Menzies. (c.) Cue. Price, 1s. 1897.
- Annual Progress Report for the Year 1897. (*Out of print.*) 1898
- Annual Progress Report for the Year 1898, containing—
Location 1830, Avon District ; Gold Discoveries on the Ditchingham Estate, Brunswick River ; Collie Coalfield ; Proposed Boring for Artesian Water in the Eastern Agricultural Districts ; The Country between Cape Riche and Albany ; The Wongan Hills ; The Artesian Water Prospects of the vicinity of Moora ; A Geological Reconnaissance of the Country at the heads of the Murchison and Sandford Rivers, in the Murchison, East Murchison, and Peak Hill Goldfields ; Gold Discoveries at Donnybrook ; Norseman Public Battery, and the use of Brines in Gold Extraction ; Mineral Waters ; Mineralogical and Petrological Notes ; Kalgoorlie ; Menzies. Price, 1s. 1899.
- Annual Progress Report for the Year 1899, containing—
Notes on the Greenbushes Tinfield ; Boring for Water at Mulgarrie ; Boring for Water at Hayes' New Find ; the Geology of the Bardoc District ; On the Development of Mining in the locality of Donnybrook ; The Geology of the North Lead, Kanowna ; The Kanowna Great Boulder, G.M.L. 885x ; Mineral Waters ; Composition of Native Gold ; Greenbushes Tin Ore ; Cobalt Ores ; Menzies Goldfield ; Kalgoorlie Goldfield ; Coolgardie Goldfield. Price, 1s. 1900.
- Annual Progress Report for the Year 1900, containing—
Kalgoorlie Goldfield ; Phillips River Goldfield ; Gold Finds on the Preston and Ferguson Rivers ; The Present Condition and Future Prospects of the Greenbushes Tinfield ; Boring for Coal near Albany ; North Lead, Kanowna ; Bulong Deep Leads ; Coolgardie Deep Leads ; Alluvial Deposits, Donnybrook Goldfield ; Subsidy to the Norseman Gold Mines, Ltd. ; Gascoyne District ; Extension of Artesian Water-carrying strata from South Australia. Price, 1s. 1901.
- Annual Progress Report for the Year 1901, containing—
Kimberley ; Uaroo Find, Ashburton River ; Gascoyne ; The Island, Lake Austin ; Mount Ida ; Yardarino Bore ; The Dundas Goldfield ; The Phillips River Goldfield ; Norseman Gold Mines, Ltd. ; Alluvial Deposits, Siberia. Price, 1s. 1902.
- Annual Progress Report for the Year 1902. (*Out of print.*) 1903.
- Annual Progress Report for the Year 1903. (*Out of print.*) 1904.
- Annual Progress Report for the Year 1904, containing—
Pilbara Goldfield ; Notes on a Traverse from Marble Bar to Roebourne ; State Aid for Boring, Peak Hill ; Mount Morgans ; The Occurrence of Telluride Ore at Mulgabbie ; Southern Cross ; Norseman ; Reported Tin Find at Cuballing ; Reward Lease at Newcastle, Toodyay District ; Boring for Coal, Napier River ; Reputed Petro-liferous Deposits of the Warren and the Donnelly Rivers ; Opal at Coolgardie. Price 1s. 1905.

Annual Reports—*continued.*

Annual Progress Report for the Year 1905, containing—

Pilbara Goldfield; Wodgina Tinfeld; Mt. Margaret Goldfield; New Find 60 miles E.N.E. of Duketon; Windanya Group of Leases, Broad Arrow Goldfield; Wagin District; Sunbeam Lease, No. 1121x, Kanowna; Northam District; Recent Mining Developments at Greenbushes; Boring for Coal near Mullewa. Price, 1s. 1906.

Annual Progress Report for the Year 1906, containing—

State Aid towards the Development of the North End of the Kalgoorlie Goldfield; Mineral Discoveries at Narlarla, West Kimberley District; Cue, Day Dawn, and Cuddingwarra; Barramie and Errolls; Lawlers, Mount Sir Samuel, Mount Ida, Darlot, and Wilson's Patch; The Saxon Lead Mine, Northampton; Wagin; Arrino and Yandanooka; Clay Deposits of the Clackline District; Beverley District. Price, 1s. 1907.

Annual Progress Report for the Year 1907, containing—

Artesian Water Boring in the Murchison, Gascoyne, and Kimberley Districts; The Country between the Gascoyne and Roebourne; Boring for Coal at Dépôt Hill, Irwin Coalfield; Boring for Coal at Eradu, Greenough River; Deep Boring on Fraser's Mine, Southern Cross; Alternative Dam Site at Kelmscott; The Mount Malcolm Copper Mine, Eulaminna; Guano Deposits at Watheroo; Reported Gold Discoveries at Mundijong; Boring for Artesian Water, West Kimberley; Boring near Wyndham; Wolfram and Tin near Brookton; Copper Deposits at Yandanooka. Price, 1s. 1908.

Annual Progress Report for the Year 1908. (*Out of print.*)

1909.

Annual Progress Report for the Year 1909. (*Out of print.*)

1910.

Annual Progress Report for the Year 1910, containing—

Results of Boring for Artesian Water on the Eucla Plateau; The Geology of the Country between Sandstone and Lawlers, East Murchison Goldfield, from the point of view of Railway Communication; The Prospects of obtaining a Water Supply for Geraldton, either Artesian, Sub-artesian, Wells or Catchment Areas; The Mount Egerton Diggings, Peak Hill Goldfield; Report upon the May Queen, G.M.L. 952, Yilgarn Goldfield, with regard to the loss of the reef due to faulting; Some notes on the Principal Geological Features of the Kalgoorlie Goldfield; Further Notes on the Gingin Chalk. Price, 1s. 1911.

Annual Progress Report for the Year 1911 (Administrative Report only) Price, 1s. 1912.

Annual Progress Report for the Year 1912. (*Out of print.*)

1913.

Annual Progress Report for the Year 1913, containing—

Dominions Royal Commission; British Association for the Advancement of Science; Reputed Occurrence of Oil in Western Australia; Meteorites; Ore Deposits of P.As. 815C and 818C, Leonora; Limestone Deposits of the South-Western Division; The Gold Belt of the Yilgarn Goldfield; Ora Banda; Mount Magnet, Lennonsville, and Boogardie; Yuin and the Royal Standard Mine; Darlot Deep Lead; Physiological Geology of Western Australia; Country between Latitude 23° and 26° South, and Longitude 119° and 121° East; Meekatharra; Sandstone; Mikhaburra (Holden's Find); The North End, Kalgoorlie; Country between Kalgoorlie and Coolgardie; The Bremer Range Country. Price, 1s. 1914.

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Cement-making Materials in W.A.; Possibility of the occurrence of Potash Deposits in the Salt Lake Areas and elsewhere in W.A.; Interstate Conference on Artesian Water Supplies; Reputed Tin Find at Brookton; Geology of the Transcontinental Railway Line; Boring for Water on the Transcontinental Railway Line; Deep Boring at Moora in its Geological Relationships; The Geology and Mineral and allied Resources of the Coastal Plains of the South-West Division; Westonia and Surrounding District; Yerilla; Golden Butterfly Mine, Butterfly, near Kookynie; Niagara; The Country South of Nullagine; Molybdenite at Swan View; Meekatharra and Surrounding Country; Greenbushes; The Country between Kalgoorlie and Mulline; The North End, Kalgoorlie; The Geology of the Mount Jackson and Koolyanobbing Districts. Price, 1s. 1915.

Annual Progress Report for the Year 1915, containing—

Building Stones of Western Australia; Limestone Deposits near Denmark; Foraminiferal Sand Deposits of Dongara, with an Appendix on their commercial application; Limestone Deposits of the Geraldton District; Supplementary Report on Limestone Deposits at Yonga (Martyup); Yilgarn Goldfield; Kookynie and Tampa; Albany; Reported occurrence of Oil near Wonnerup, with an Appendix on the supposed Petroleum-bearing Earths and Water; Meekatharra; North End, Kalgoorlie; Magnesite Deposits at Bulong, North-East Coolgardie Goldfield; Geological Report on the Canning River Dam Site, No. 2; Occurrence of Gold at North Dandalup; Yerilla District. Price, 1s. 1916.

III.—BULLETINS.

- I. Bibliography of the Geology of Western Australia : by A. Gibb Maitland, Government Geologist. Price, 1s. 1898.
- II. The State of Mining in the Kimberley District, and the probability of obtaining Artesian Water between the Pilbara Goldfields and the Great Desert : by R. Neil Smith. (*Out of print.*) 1898.
- III. The Coolgardie Goldfield : by Torrington Blatchford, Assistant Geologist. Price, 1s. 1899.
- IV. The Mineral Wealth of Western Australia : by A. Gibb Maitland, Government Geologist. Price, 1s. 1900.
- V. The Phillips River Mining District : by Torrington Blatchford, Assistant Geologist. Price, 1s. See Bulletin xxxv. 1900.
- VI. Notes from the Departmental Laboratory : by E. S. Simpson, Mineralogist and Assayer. (*Out of print.*) 1902.
- VII. The Auriferous Reefs of Cue and Day Dawn : by W. D. Campbell, Assistant Geologist. Price, 1s. See Bulletin XXIX. 1903.
- VIII. Lennonville, Mount Magnet, and Boogardie, Murchison Goldfield : by C. G. Gibson, Assistant Geologist. Price, 1s. 1903.
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- X. Palaeontological Contributions to the Geology of Western Australia. I. Carboniferous Fossils from the Gascoyne District : by R. Etheridge, jun. Price, 2s. 1903.
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- XIV. A Part of the Murchison Goldfield : by C. G. Gibson, Assistant Geologist. (*Out of print.*) 1904.
- XV. Preliminary Report on the Pilbara Goldfield : by A. Gibb Maitland, Government Geologist. (*Out of print.*) For reprint see Bulletin XI. 1904.
- XVI. Mineral Production of Western Australia up to 1903 : by A. Gibb Maitland, Government Geologist, and C. F. V. Jackson, Assistant Geologist. (*Out of print.*) 1904.
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- XXI. The Norseman District, Dundas Goldfield : by W. D. Campbell, Assistant Geologist. (*Out of print.*) 1906.
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- XXXIX. The Country between Wiluna, Hall's Creek, and Tanami: by H. W. B. Talbot, Topographical Surveyor. Price, 2s. 1910.
- XL. The Pilbara Goldfield: (Reprint of Bulletins, 15, 20, and 23) by A. Gibb Maitland, Government Geologist. Price, 2s. 6d. 1908.
- XLI. The West Pilbara Goldfield: by H. P. Woodward, Assistant Government Geologist. (*Out of print.*) 1911.
- XLII. The Geology and Ore Deposits of Kalgoorlie, Part I.: by E. S. Simpson and C. G. Gibson. Price, 2s. 6d. 1912.
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- XLIX. The Geology and Mineral Resources of Yilgarn Goldfield, Part I., Southern Cross: by E. C. Saint-Smith and R. A. Farquharson. (*Out of print.*) 1913.
- L. The Geology and Mineral Industry of Western Australia: by A. Gibb Maitland and A. Montgomery. Price, 2s. 6d. 1912.
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- IX. General Index to Reports, 1870-1910. Price, 2s. 6d. 1916.
- LXI. Physiographical Geology of Western Australia: by J. T. Jutson, Field Geologist. (*Out of print.*) 1914

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- LXV. Reputed Petroliferous Area of the Warren River District, South-West Division : by H. P. Woodward, Assistant Government Geologist. Price, 2s. 6d. 1915.
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In the Press :—

- LXVIII. The Geology and Ore Deposits of Meekatharra : by E. deC. Clarke, Field Geologist.
- LXIX. Contributions to the Study of the Geology and Ore Deposits of Kalgoorlie, Part III.—The North End of Kalgoorlie : by F. R. Feldtmann, Field Geologist.
- LXX. The Western Australian Mining Handbook : edited by A. Gibb Maitland, Government Geologist.

In Preparation :—

- The Geology and Mineral Resources of the Maritime Districts of the South-West Division (Lime, Cements, Clays, etc.) : by H. P. Woodward, Assistant Government Geologist.
- The Geology and Mineral Resources of the Country South of Nullagine : by H. W. B. Talbot, Field Geologist.
- The Geology and Mineral Resources of the Yilgarn Goldfield, Part III.—The Districts North of Southern Cross : by T. Blatchford and C. S. Honman.
- The Mining Geology of Niagara, Kookynie, and Tampa, North Coolgardie Goldfield : by J. T. Jutson, Field Geologist.
- The Artesian Water Resources of Western Australia : by A. Gibb Maitland, Government Geologist.
- Palæontological Contributions to the Geology of Western Australia, VI. : by F. Chapman.

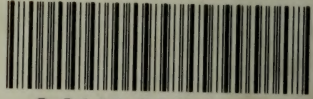
IV.—MEMOIRS.

In preparation :—

1. The Geology and Mineral Resources of Western Australia : by A. Gibb Maitland.

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